The Physiologist

A Publication for Physiologists and Physiology
Ray G. Daggs, Editor

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The seal at the top of this page was designed by William F. Hamilton and has been adopted by the Council as an official emblem of the Society.

Editor's Page

The first volume of THE PHYSIOLOGIST will consist of five numbers, November 1957 through November 1958. This is done in order to have the future volumes start with the February issue and be contained within one calendar year.

The editor again invites members to submit material for publication in THE PHYSIOLOGIST. News items and special announcements are welcome. Brief articles of general interest to all physiologists are particularly welcome. These may be articles of an historical yet personal nature like the one in this issue on L. J. Henderson by D. W. Richards; brief discussions of new methods or techniques in research and/or laboratory teaching; broad philosophical articles; witty or satirical bits; or anything that would make interesting reading for physiologists. It will be impossible to please everyone but a wide variety of material, we believe, will hold the widest audience.

Webster defines physiology as a branch of biology dealing with the processes, activities and phenomena of life and living organisms; the study of the functions of the organs and parts during life; and physiologist as one versed in physiology. Let us paraphrase and think of THE PHYSIOLOGIST as an organ disseminating information of the activities and life of physiologists and the functions of APS, its local groups and individuals.

New Journals

PROSPECTIVES IN BIOLOGY AND MEDICINE - a new journal sponsored by the Division of Biological Sciences at the University of Chicago - will attempt to provide the continuity which has been lacking in the fields of biology and medicine. The journal is dedicated to the presentation of new ideas in the field which will stimulate original thought and investigation. Articles appearing in the journal are designed to:

> Emphasize the interrelation of the medical and biological sciences.
> Take stock of the results and implications of recent and current research and indicate research strategy for the future.

ARTHRITIS AND RHEUMATISM - the official journal of the American Rheumatism Association - will cover the field of connective tissue disorders, in particular rheumatoid arthritis, osteoarthritis, rheumatic fever, gout, the so-called collagen diseases, and nonarticular rheumatism. Publisher - Grune and Stratton, Inc., New York.

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ATTENDANCE AT FALL MEETINGS

	Registrants	Guests	Total	Papers
Minneapolis, Minnesota 1948	422	34	456	186
Augusta, Georgia 1949	227	36	263	137
Columbus, Ohio 1950	442	20	462	244
Salt Lake City, Utah 1951	337	71	408	240
New Orleans, Louisiana 1952	388	113	501	241
No meeting 1953	---	--	---	---
Madison, Wisconsin 1954	570	77	647	268
Medford, Massachusetts 1955	704	43	747	325
Rochester, New York 1956	417	106	523	226
Iowa City, Iowa 1957	513	103	616	228

SECOND BOWDITCH LECTURE*

The Resourcefulness of Nature in Physiological Adaptation to the Environment

Bodil Schmidt-Nielsen

From the Department of Zoology, Duke University, Durham, North Carolina

It is a great privilege to present this lecture in honor of Dr. Bowditch. Dr. Bowditch's many achievements and contributions to science are awe-inspiring, and yet, when reading about him, two things in particular gave me a warm feeling of kinship. When he as a young man spent a year of training in Europe he wrote to his parents, "I wish I could see a real good opening for a purely scientific career." The other thing is that while he was in Paris he formed hilarious frog hunting parties together with his friends, John Collins Warren, William James, Ranvier and Charles Emerson. Not only have I myself enjoyed some frog hunting parties on quaking bogs in Maine, but I have also been on camel and kangaroo rat hunting parties as well. I can wholeheartedly agree with Dr. Bowditch that physiological research, and particularly field work, is the most attractive work one can find.

The resourcefulness of nature in adaptation to the environment is wonderful and it makes physiological studies most intriguing. I have given the title a rather wide scope and I must admit that I intend to restrict myself to talk about adaptation to one particular environment, namely the hot desert. The hot desert is a hostile environment to most animals. In the summer the heat is intense, the sun shines directly from above, the radiation is high, the vegetation is scant, and water is scarce.

Man himself, being a tropical animal, is poorly equipped to withstand this environment. A man left in the desert without water during the hottest time of the year will die after 1 or 2 days of exposure. In the same environment a number of mammals thrive with little or no water at all. Rodents are plentiful. In the New World deserts we find kangaroo rats and pocket mice, in the Old World deserts jerboas, meriones, gerbils, and many other similarly adapted rodents. Among large animals we have the gazelle and a domesticated animal, the camel.

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* The annual Bowditch Lectureship in honor of the first elected President of the American Physiological Society, Henry Pickering Bowditch, was established in 1956. The lecturer is selected by the President of the Society from among the members who have done outstanding work and are under 40 years of age. Funds for the honorarium are given to the Society by an anonymous donor. The lecture is given as a formal presentation at the Fall Meeting of the Society. The first Bowditch Lecture, titled "Role of the red blood corpuscles in the regulation of renal blood flow and glomerular filtration rate" was given in 1956 by John R. Pappenheimer of Harvard Medical School.

How do these animals do what man cannot do? What physiological mechanisms do they have that enable them to withstand an environment so hostile to man? The main question is how these animals manage to maintain water balance, because the heat, though fierce, can be tolerated even by man if he has sufficient water to cover his needs.

First, we will look at the water balance sheet for intake and output (table 1). We can use this balance sheet as an outline for the following discussion. On the output side we have the evaporation, the urine

Table 1 WATER BALANCE

OUTPUT		INTAKE
Evaporation	Sensible Insensible	Drinking Water
Urine		Preformed Water in Food
Feces		Oxidation Water

and the water in the feces. On the intake side: drinking water, preformed water in the food and oxidation water. To many of the desert dwellers drinking water is simply not available, not even as dew, which does not occur except after heavy rains. The amount of preformed water that an animal gains from the food varies of course according to the dietary habits of the animal and according to the season. The amount of water gained from oxidation depends on the metabolic rate and the type of foodstuff metabolized.

Evaporation

We can divide the evaporative water loss from the body into the sensible and the insensible perspiration. The sensible perspiration is the evaporation used and regulated for maintaining the body temperature. The insensible perspiration is the evaporation that takes place from the surface of the body and from the respiratory tract. The amount cannot be regulated but it will vary with the absolute humidity of the air which is inspired.

Let us first consider the sensible water loss. Whenever the environment is so warm that the heat transfer between body and environment results in a net heat gain in the body, water must be evaporated if the body temperature is to be maintained at a constant level. In a hot environment heat gain is approximately proportional to the body surface area. Heat gain from conduction and convection from the hot air, from radiation from the sun and the surface of the ground, and from metabolism, all are approximately proportional to the body surface area. The small kangaroo rat, with a body weight of about 100 gm, has a surface area of approximately 3000 cm^2 per kg, while the large camel, weighing about 500 kg, has a surface area of only 130 cm^2 per kg. In other words, the relative surface area of the kangaroo rat is roughly 20 times higher than that of the camel and, therefore, the heat gain per unit weight will be about 20 times that of the camel.

In figure 1 is shown the amount of water that animals of various body sizes will have to evaporate in order to maintain the body temperature during the heat of a summer day in a hot desert. The figures for man, dog and donkey are values measured by Dill and Adolph (1-3). The

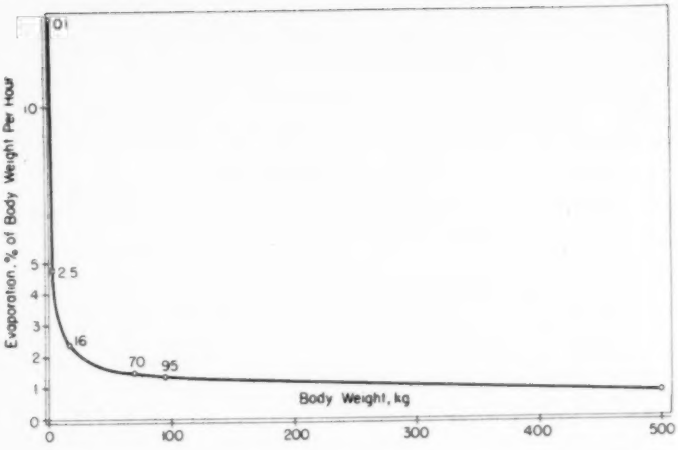


Fig. 1 The curve shows the rapid increase in evaporation of mammals with diminishing body size. Curve is based on estimated hourly evaporation of mammals of different body size under desert conditions (13). Figures for dog, man and donkey are calculated from data reported by Dill and Adolph (1-3).

figures for kangaroo rat and camel are not measured but only calculated on the basis of the relative surface area of these animals. It is clear from this graph that a small animal without access to drinking water cannot possibly survive in the heat for more than 1 or 2 hours, because water corresponding to 13% of the body weight is lost every hour. This was also clearly evident during our work in Arizona. Kangaroo rats placed in the laboratory where we worked died from heat stress within about 1 hour. However, the desert rodents do not expose themselves to the heat of the desert. They are nocturnal. During the daytime they stay in their underground dens where the temperature is at all times so low that evaporation for heat regulation is unnecessary. Vorhies (20) showed that the temperature in the nest chamber in the burrow of a banner-tailed kangaroo rat remained around 30°C even during the hottest part of the year. Similar low temperatures were observed by ourselves (8).

The camel, in contrast to the small rodent, has to stay in the heat of the desert. It cannot dig itself down into the ground like the kangaroo rat. From figure 1 it can be seen that the camel, in order to maintain body temperature in the hot environment, should spend approximately 0.7% of its body weight per hour, or 7% per day if the heat lasts approximately 10 hours. Actual measurements of the amount of water spent per day by a camel in Sahara showed that much less water was spent (12). From figure 2 it can be seen that while a donkey in the summer months in Sahara spent approximately 10 liters of water per 100 kg

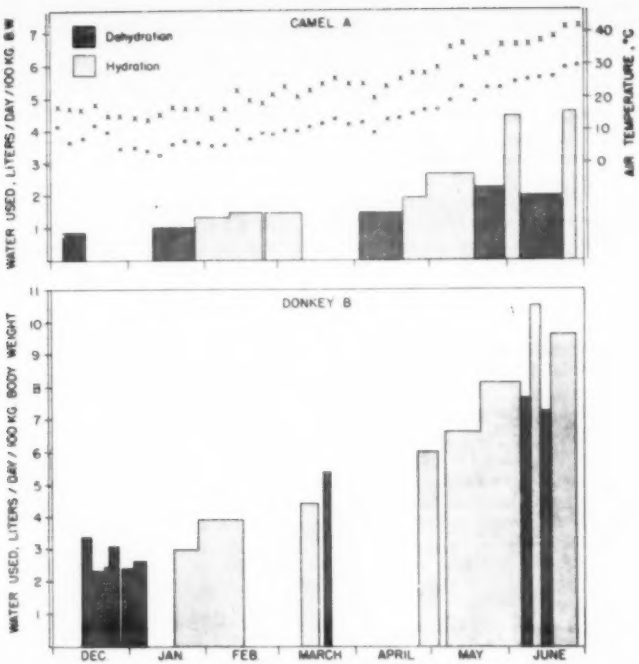


Fig. 2 Rate of water expenditure of Camel A and Donkey B. Ordinate: water expenditure per day in l/100 kg body weight., expressed as the amount of water used by the animals in excess of the water formed by oxidative metabolism. Average air temperature at 6 a.m. (0) and 3 p.m. (X) approximately represent maximum and minimum daily temperature. They indicate the variations in heat load in the various periods, but are a rather inadequate expression of heat load because animals were exposed to direct radiation from the sun and from the environment and because the velocity of the wind was variable (12).

body weight per day, the camel was spending only about 4 liters. The donkey spent about the same amount as determined by Dill in Nevada but the camel spent only a little over half the amount calculated on basis of its body size.

Another thing that is even more important is that the camel spent less water in periods when it was deprived of drinking water than in periods when it had access to drinking water. To understand how the camel does this we must look at its temperature regulation.

The calculated figures for the water expenditure of the camel were based on the assumption that the camel maintains constant body

temperature. According to the literature, some observations on the rectal temperature of camels indicated that this may not be so (15).

In our studies the rectal temperature of the camel was measured for extended periods for winter and summer (17). In figure 3 is shown the rectal temperature as it varies in the camel when it has drinking

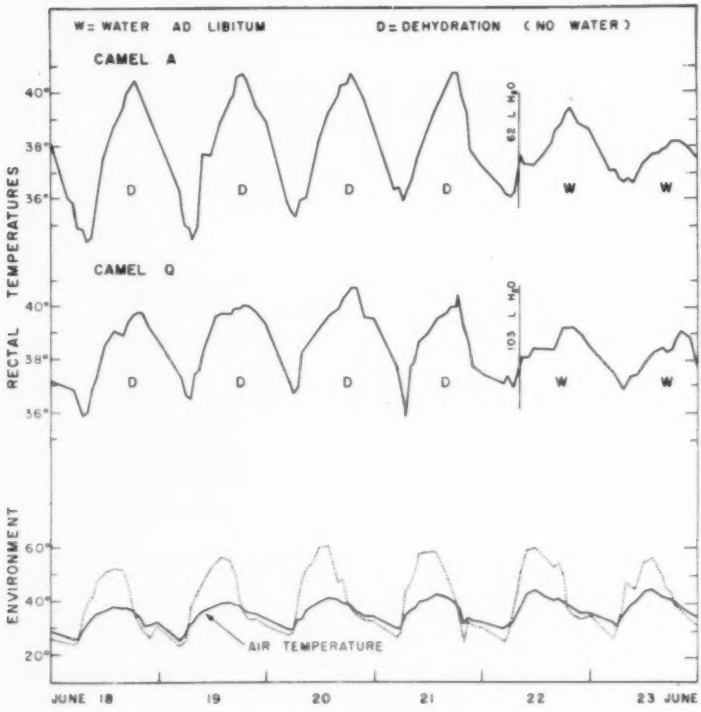


Fig. 3 Rectal temperatures of 2 camels in the period 18-23 June, showing in detail effect of rehydration in reducing diurnal temperature fluctuations (17).

water, and when it is kept without water. It is seen that the camel does not maintain a nearly constant body temperature as does man. The rectal temperature of a camel without drinking water varies from a value below 35°C early in the morning to a value close to 41°C, in other words, it varies 6°C in the course of 12 hours while in man it varies only 1°C. As you will see (figure 3) these wide temperature excursions are only found during the periods when the camel is deprived of water. As soon as the camel has access to drinking water it does not any longer permit the body temperature to vary over such a wide range. It should be emphasized that these temperature excursions do not appear to be associated with a general break-down in heat regulation of the camel, since

this type of temperature curve is found only a few days after water deprivation has started, while the camel is still in excellent physical condition. It appears to be a physiological adaptation that enables the camel to reduce its water loss.

Through this mechanism of permitting the body temperature to rise the camel saves water in two ways. While the body temperature is increasing the camel stores calories in the body instead of spending water for heat dissipation. Secondly, when the temperature of the skin is increased through the rise in body temperature, heat gain from the environment is reduced. The reduction in heat gain is brought about through the decrease in heat gradient from air and soil to the surface of the camel.

We can make an approximate estimate of the heat gain from the environment during the periods of water deprivation and the periods of free water intake. The calculation is based upon the amount of water spent for heat regulation and an estimate of the amount of calories stored in the body, assuming that the rectal temperature represents an average body temperature (17). (This of course is only approximately true.) The amount of heat that has been stored plus the amount of heat that has been dissipated must equal the total heat gain. By substracting the amount of heat gained by the metabolism we can calculate the heat gained by radiation, convection and conduction. As you will see from figure 4, the saving in water that is accomplished during periods

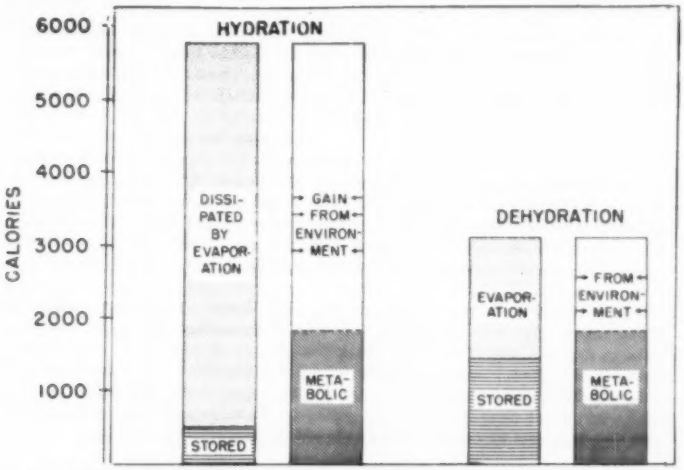


Fig. 4 This graph shows how much the heat gain from the environment is reduced in a 260-kg camel when deprived of drinking water. Heat gain from the environment is calculated by subtracting estimated metabolic heat production from the total heat gain for the 10 hr. during which the ambient temperature and radiation are highest. Since heat gain from the environment can only be influenced by physical factors such as surface temperature and exposed surface area, the greater part of the difference between the dehydrated the hydrated camel seems to be due to changes in body temperature (17).

of dehydration (when the body temperature is permitted to increase to almost 41°C) is particularly high because the heat gain from the environment is reduced to about one third of the value it had when the body temperature was maintained at a lower level. The heat stored in the body during the day can be dissipated during the night when the air is cool.

Besides the rise in body temperature which effectively decreases heat gain, the camel has other means of reducing heat influx from the environment. It has a woolly coat on its back which acts as a heat barrier. In the winter time the neck, trunk and legs of the camel are covered with a thick coat of wool. In the spring, part of this wool is shed, but while it is shed effectively on neck, legs and abdomen, it remains on the back of the camel.

Several simultaneous measurements of water expenditure in two camels, one sheared and the other with its natural coat, showed that the sheared camel used about 1.5 times as much water as the other camel. In a later experiment the water expenditure of the two camels was compared when both were sheared. Under these circumstances the water expenditure was the same. These findings agree well with observations on the effect of clothing as a heat barrier in man (5). The fact that the sensible evaporation of the camel is considerably lower than the calculated value can be explained in a quantitatively satisfactory way through: 1) the effectiveness of the fur as a heat barrier and 2) the controlled rise in body temperature which reduces heat gain.

The insensible evaporation takes place from the respiratory tract and the surface of the skin. The air that is inhaled becomes saturated with moisture in the respiratory tract and its temperature becomes equal to that of the body. In man the exhaled air is saturated with moisture at a temperature of approximately 33°C. On the basis of the utilization of alveolar oxygen, we can calculate the amount of water that must be evaporated from the respiratory tract per ml of oxygen taken up if we know the absolute humidity of the inhaled air. If the inhaled air is absolutely dry, 0.84 mg of water per ml of oxygen taken up is evaporated from the respiratory tract in man. This figure should be the same for all mammals that have the same utilization of oxygen in the lungs and the same temperature of the exhaled air.

In order to see if the kangaroo rats could reduce the water loss from the lungs, we measured the total evaporation from the kangaroo rats in dry air simultaneously with the oxygen uptake (9). The evaporation that we found turned out to be considerably lower than the loss calculated from the lungs alone. On the average, 0.54 mg water evaporated per ml of oxygen taken up, while in white rats and mice the actual evaporation was close to the calculated value.

The low values in the kangaroo rats were difficult to explain, and for a while we believed that it was possible that these animals had an increased utilization of oxygen in the lungs. However, the oxygen dissociation curve of their blood showed no deviation from that of other mammals (4). The final answer turned out to be much simpler. The exhaled air is saturated not at the temperature of the lungs, but at the temperature of the nose. By measuring the nose temperature in kangaroo rats and white rats, we found that this is not approximately 33°C as it is in man but only 26-28°C. When the evaporative loss is calcu-

lated on the basis of this temperature, the calculations gave a value almost identical to the measured value. It should be noted in this connection that the difference measured in evaporation from kangaroo rats and white rats is not due to a difference in evaporation from the respiratory tract, since white rats have the same low nose temperature as the kangaroo rats. The difference must be due to difference in evaporation from the rest of the body surface. The kangaroo rats, having virtually no sweat glands, also have a very low evaporation from the body surface aside from the respiratory tract.

The kangaroo rat stays in its burrow for a considerable part of the 24-hour period. The air that it breathes in its burrow contains more moisture than the air outside. We were interested in calculating how much water the kangaroo rat saves when it respires the more humid air in its burrow, and it was therefore necessary to measure the absolute humidity in its nest chamber (8). In order to do this we tied a microclimate recorder to the tail of a kangaroo rat and released the animal in front of its own burrow. The animal would then take the recorder with it down into its next chamber and after 10-12 hours we could dig out the instrument and thus obtain complete records of temperature and humidity in the undisturbed burrow with the animal 'at home'. Measurements from a number of burrows showed that the humidity inside the burrows is normally much higher than outside. This is due to the fact that the sand in the desert always contains a considerable amount of moisture. While the air outside the burrow usually had a water content of some 2-5 mg water per liter of air, the air inside the burrow had a water content around 8-10 mg per liter of air. If the expired air, as we have calculated from the nose temperature, contains 24 mg of water per liter of air, the amount that evaporates from the lungs is 20-22 mg per liter of air when outside air is respired, while it is only 14-16 mg per liter when the animal respires the air in the burrow.

Urine

The minimum urine volume in man is about 0.5 liters per day. At the same time, man spends about 10 liters per day for cooling in the desert. If he could reduce his urine volume to one-half by excreting twice as concentrated a urine, the saving would still be very insignificant in view of the over-all expenditure. However, for the desert rodent with a minimal evaporative water loss, the urine volume represents about one-third of the total expenditure and a reduction in urine volume becomes highly significant.

From table 2 it is seen that the desert rodents do indeed excrete a very concentrated urine. The maximum concentrations of both electrolytes and urea are 3 to 4 times higher in the desert rodents than they are in man (7, 18). The electrolyte concentration in the kangaroo rat

Table 2
Maximum Concentration of Electrolytes and Urea in Urine

	Electrolytes	Urea
Man	0.37 N (2.2%)	1.0 M (6%)
Norway rat	0.60 N (3.5%)	2.5 M (15%)
Heteromyids	1.2 N (7%)0	3.8 M (23%)

urine can be more than twice the concentration of sea water. From this one should expect, then, that these animals should be able to utilize sea water for drinking water. This was also found to be the case. Animals maintained on a high protein diet and who therefore had to ingest water in order to excrete the quantities of urea produced, drank sea water and maintained body weight as well as animals given fresh water (10), while a group of animals maintained on the same diet but without water lost weight rapidly.

Total osmolarity of the urine of the kangaroo rats can be calculated to be about 6 osm. In man the maximum osmalarity of the urine is only around 1.2.

For the camel a saving in the urine volume is also of significance, since the over-all expenditure of water for cooling is relatively low. Camels are known to be able to feed on plants with a high electrolyte content (Traganum and Salicornia). The maximum concentration that we have determined in the urine of the camel is 3.2 osmolal. This value may, however, not represent the maximum concentrating power of the camel kidney.

We now come to a very interesting question, which is: What is peculiar about the kidney of desert animals that enables them to excrete a urine with such exceptionally high concentrations? In examining the kidneys of various desert rodents, we find that they are peculiar in that the papilla renis is exceedingly long and reaches far down into the ureter. This peculiarity is shared by other rodents living in similar dry habitats (19). In larger animals we do not find the single papilla type kidney. However, in large animals from dry habitats, such as the gazelle, the lion, the camel and the giraffe, we find that the relative thickness of the medulla is greater than in other mammals and that the water-loving mammals have the lowest relative thickness.

It has been suggested by Hargitay and Kuhn that the kidney operates as a counter-current multiplier system. According to this hypothesis, the maximum concentration that can be created in the tip of the papilla, and therefore in the urine, must be proportional to the length of the longest of Henle's loops in the kidney. Since the longest loops reach all the way to the tip of the papilla, the length of the papilla (or the thickness of the medulla) should be roughly proportional to the maximum concentration that a kidney can produce.

The hypothesis by Hargitay and Kuhn has not yet been universally accepted. However, there is considerable evidence in support of this hypothesis, and in my opinion the morphological features just discussed form a strong piece of evidence in its favor (6).

Water Expenditure in the Feces

In desert animals living on a dry diet, the water expenditure in the feces is much reduced when compared to that of non-desert animals. Table 3 shows that the percentage of water in the feces of both kangaroo rat and camel is of the same order of magnitude, about 75% on a dry weight basis, while in man and white rat the percentage is around 200. In the camel on a constant diet, it was also found that the water content of the feces varied with the hydration of the body. The amount of water lost in feces varies, of course, not only with the percentage of water in

Table 3
Water in feces. Grams per 100 g dry matter

	Hydrated	Dehydrated
Kangaroo rat	--	83
White rat	225	--
Donkey	181	--
Man	185	--
Camel	109	78
Cow	566	--

the feces but also with the amount of feces produced on a certain caloric intake. The amount varies with type of diet. The rodents have a distinct advantage over the ruminant because much less feces is produced per calorie.

Account for the Total Water Expenditure

On the basis of our determinations it is possible to set up an account for the total water output. In figure 5 this account is shown for

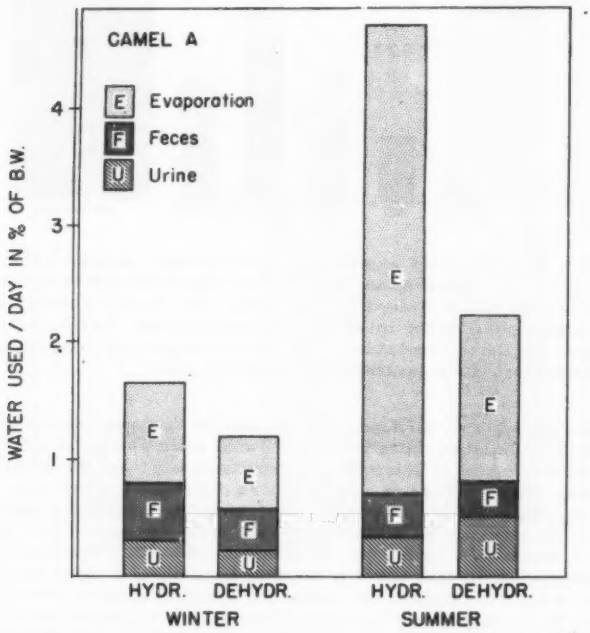


Fig. 5 Water expenditure for urine, feces and evaporation in Camel A for periods of hydration and dehydration in summer and in winter. The higher urine flow in the two summer periods is due to increased salt and protein in the experimental diet during these periods. Ordinate: total water expenditure in l/day/100 kg body weight (12).

the camel. It is seen that the water output is considerably higher in the summer than in the winter, and that the difference is due to the difference in evaporation. When periods in which the camel was given drinking water are compared with periods in which it was deprived of water, it is seen that there is a very significant difference in water expenditure between such periods in the summer, while in the winter the difference is rather insignificant. The marked difference in evaporation between periods of hydration and dehydration in the summer is, as already discussed, due to the peculiar heat regulation of the camel during dehydration.

In figure 6 the minimum water expenditure in various animals has been calculated as liters of water spent per liter of water formed

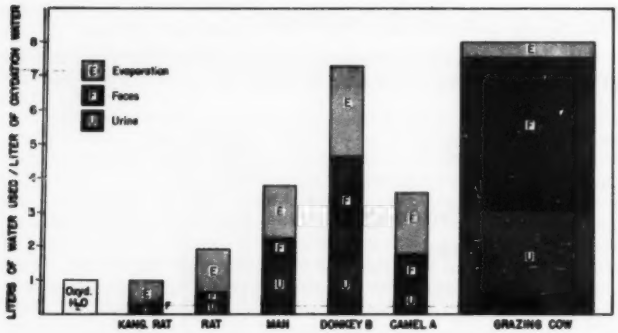


Fig. 6 Minimum water expenditure in different mammals presented as liters of water spent per liter of water formed by metabolic oxidation (12). Except for the cow, this is calculated as the minimum expenditure in an environment so cool that no water is spent for heat regulation. Data for cow represent average water expenditure in a grazing, nonproducing cow.

by the oxidation of the food. We see that the kangaroo rat can depend entirely on oxidation water because the total water expenditure does not exceed the amount of water formed simultaneously from the oxidation of the food. These values are calculated for a diet relatively low in protein, such as barley. The evaporation is calculated for a humidity somewhat below the humidity of the burrow. When the water expenditure and the water intake on a barley diet were calculated for different humidities, it was estimated that below an absolute humidity of 2 mg of water per liter of air the kangaroo rat should not be able to maintain water balance, while at any humidities above this value the animal should be able to stay in water balance without drinking water. That these estimations were very nearly correct was verified experimentally by keeping kangaroo rats at different humidities (11). At humidities below the estimated lower limit the kangaroo rats lost weight. At a humidity close to the limit, body weight was barely maintained, while at higher humidities the kangaroo rats all gained weight.

The camel, in contrast to the kangaroo rat, is at all times de-

pendent on preformed water. The data for evaporation given in the figure represent the evaporation when water is not used for cooling. When comparing the camel with man, it is seen that although the camel can concentrate its urine to a considerably higher degree than man, the over-all water expenditure of the camel is not much lower than that of man. This is particularly due to the large volume of feces excreted by the ruminant.

It is in the summer time that the camel as a desert animal has a real advantage over man (fig. 7) because of the economy with which water is spent for cooling.

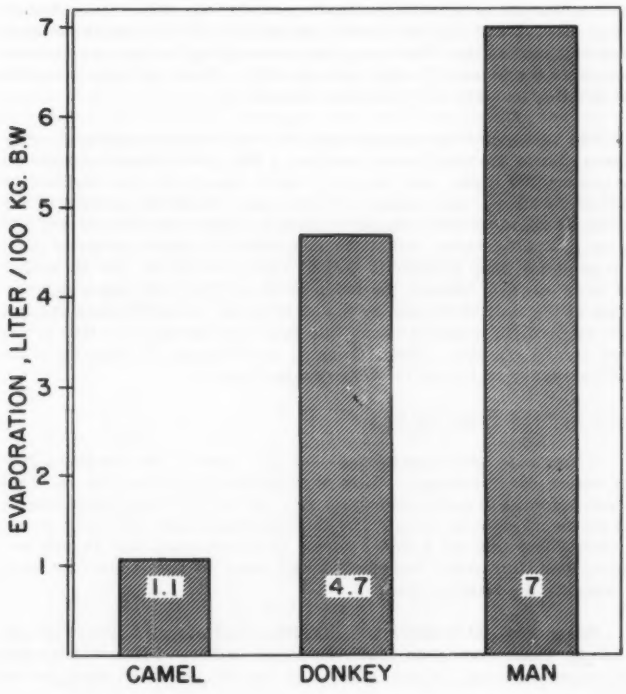


Fig. 7 Water used for cooling in summer, in excess of that used in winter, in animals exposed to direct sunlight in the desert in the month of June, given as 1/day/100kg body weight (12). Figures for the camel and the donkey are figures from periods when the animals were deprived of water. The figure for man is calculated from Adolph, who found no decrease in sweating rate when man became progressively dehydrated.

Is Water Stored in the Rumen?

We have seen that the camel cannot get along without water, but it can reduce its water expenditure. It thus needs water from time to time, but it is known to be able to withstand water deprivation much longer than other large animals. It has been postulated since the time of Pliny that this ability is due to water storage in the rumen.

The basis for this postulation is a peculiar structure found in the wall of the rumen. The wall of the rumen is divided into a number of compartments or sac-like structures. The total volume of these sacs is about 5-7 liters. The sacs are commonly referred to as 'water sacs' or 'water cells'. However, these terms imply a function which is not supported by facts. It is true that the rumen does contain fluid, and it is also true that an Arab, if lost in the desert with his camel, sometimes as a last resort will kill his camel and drink the fluid from the rumen in order to save his life. However, there is nothing in our experiments that supports the legend of water storage (16). I will not bore you with all the details, and will only mention a few facts.

The volume of the compartment is, as already mentioned, only 5-7 liters. Since the total water loss that a full grown camel can tolerate is around 100 liters, and the daily water loss in the hot summer is around 15-20 liters, the amount of fluid that could be present in the 'water sacs' would be very insignificant in the over-all water balance of the camel. Furthermore, while the rumen of the camel normally contains a greenish soup similar to that of other ruminants, the so-called 'water sacs' always contain the more solid parts of the rumen content. Analysis of the fluid that could be drawn from the compartments showed that the electrolyte composition of this fluid was identical to that of the general rumen content. Thus, there is no evidence in support of the legend that water is stored in these compartments.

Is Water Derived From the Hump?

It has also been postulated that the function of the hump is to supply water for the camel. This postulation is based on the fact that the hump contains almost exclusively fat, and that fat when metabolized yields its own weight in water. The misconception that the hump in reality should function as a water supply is widespread, and is still repeated in the literature; therefore I will have to use a few figures to show wherein the mistake lies.

Seemingly, fat is more advantageous than starch because fat per unit weight yields twice as much oxidation water. However, fat also yields more calories. From table 4 it can be seen that when fat and

Table 4
Comparison of Foodstuff Used, Oxygen Taken up, and Water Formed
Metabolic level 10,000 kcal

	Foodstuff Used kg	Oxygen Used for Oxidation of Food liter	Oxidation Water Formed kg	Approx. Water Evap. from Lungs in Dry Air kg
Fat	1.06	2130	1.13	1.8
Starch	2.39	1980	1.33	1.7

starch in equivalent caloric amounts are metabolized, more water is formed from starch than from fat. At the same time the amount of oxygen used for oxidation is greater for fat than for starch. Therefore, the ventilation of the lungs, and consequently the evaporation from the lungs, is greater when fat is metabolized. It can thus be seen that starch, from the point of view of water economy, is more advantageous than fat. Furthermore, it can be seen that when dry air is inhaled the evaporation from the lungs is greater than the water gained by oxidation and that therefore no net gain of water is achieved (14, 15).

Ability to Tolerate Dehydration

The camel, then, has no water storage. When it is kept without water on a dry diet its total body water decreases. However, the amount of water that the camel can tolerate losing is amazingly high. Our camels, when deprived of water, would continue to eat, and not before an amount of water corresponding to 20-22% of their body weight was lost would they ordinarily lose appetite. They were still in good condition when the water loss amounted to 25-28% of their body weight. When offered water after a prolonged period of dehydration, the camels would usually take in the total amount of water lost in a matter of about 10 minutes (see table 5).

Table 5
COMPARISON BETWEEN THE WATER LOSS DURING WATER DEPRIVATION AND THE AMOUNT OF WATER INGESTED AT THE TERMINATION OF THE DEHYDRATION PERIOD

Day of Drinking	Wt. Before Dehydr.	Days Without Water	Weight Loss		Drinking	
			kg	% of b.wt.	kg	% of dehydr. b.wt.
Camel A						
12/14	223	9	17.3	7.8	16.3	7.9
1/27	226	17	36.5	16.2	40.0	21.1
4/19	234	17	34.0	14.5	44.0	22.0
5/29	291	11	64.0	22.0	56.0	24.9
6/22	332	17	(124)*	37.4	61.7	29.7
7/4	274	7	72.5	26.5	66.5	33.1
Camel Q						
6/12	474	7	109	23.0	103	28.1
6/22	452	8	103	22.6	103	29.4
7/4	447	7	122	27.2	104	31.8

The remarkable ability to withstand water loss raises the question of where the water is taken from. Man exposed to a hot environment cannot tolerate a loss of water corresponding to more than 10-12% of his body weight. The reason for this is that the circulation becomes impaired because of hemoconcentration. Heat cannot be brought to the body surface for dissipation, and explosive heat rise and death ensue.

Determinations of plasma volume and extracellular fluid volume were made in the same camel before hydration and after a period of dehydration in which water corresponding to 17% of the body weight was lost. It was found that the plasma volume was decreased by less than 10%, while the volume of extracellular fluid had decreased by as much as about 38%. It is possible that an ability to maintain the plasma vol-

ume is part of the adaptation to withstand dessication.

One might expect that the plasma concentrations of electrolytes might show marked changes during periods of water deprivation and rehydration. However, a camel exposed to dehydration for 17 days during the hottest part of the year did not show any marked increase in the plasma electrolyte concentrations. After rehydration, where the camel drank an amount of water corresponding to 35% of its final total body water, the lowest plasma concentrations were not reached until 48 hours after drinking. The decreases in the plasma electrolyte concentrations were not as marked as could be calculated from the amount of water ingested. The decrease in total osmolarity was only 19%. We have no explanation for this phenomenon at the present time. It may be due to a mobilization of ions as part of the adaptation to rehydration.

Summary

In summary it can be said that the desert rodents are independent of preformed water in their food. They subsist on dry food such as grain, seeds and other dry plant materials. They do not drink. Water is not available to them not even in the form of dew, except on rare occasions after heavy rains. They survive because their over-all water expenditure is so low that it does not exceed the amount of water formed by the oxidation of their food. This economy of water is accomplished through: a) a very low evaporation -- water is not used for heat regulation, and the insensible water loss is very low; b) very little water is spent for urine because these animals can manufacture a highly concentrated urine; c) the amount of feces excreted is small and the water content is very low.

The camel, on the other hand, depends on preformed water because it cannot reduce its water expenditure to less than the oxidation water. It eats fresh or dry plants and in the winter it can, when grazing, derive enough water to cover its needs through the water content of fresh plants. However, if maintained on dry plant material it needs water in the winter. In the summer a grazing camel must drink periodically.

The camel, in contrast to most other mammals, tolerates prolonged periods without water. This is due to: a) a low over-all water expenditure, particularly due to the economy with which water is spent for cooling; b) an ability to tolerate a water loss of 25-30% of its total body weight, or 40% of its total body water.

The adaptations that the camel and the desert rodents show are developed to an extreme that one would hardly expect to be physiologically possible. I want to complete this talk by emphasizing that not only is it of interest to see how various animals are adapted to their particular environment, but through such studies a great deal is to be learned about physiological principles in general.

REFERENCES

1. ADOLPH, E. F. and D. B. DILL. Observations on water metabolism in the desert. Am. J. Physiol. 123: 369, 1938.

2. DILL, D. B. Life, Heat and Altitude. Physiological Effects of Hot Climates and Great Heights. Cambridge, Mass.: Harvard, 1938.

3. DILL, D. B., A. V. BOCK and H. T. EDWARDS. Mechanisms for dissipating heat in man and dog. Am. J. Physiol. 104: 36, 1933.

4. GJØNNES, B. and K. SCHMIDT-NIELSEN. Respiratory characteristics of kangaroo rat blood. J. Cell. & Comp. Physiol. 39: 147, 1952.

5. MOLNAR, G. W., E. J. TOWBIN, R. E. GOSSELIN, A. H. BROWN and E. F. ADOLPH. A comparative study of water, salt and heat exchanges of men in tropical and desert environments. Am. J. Hyg. 44: 411, 1946.

6. SCHMIDT-NIELSEN, B. Urea excretion in mammals. Physiol. Rev. In press.

7. SCHMIDT-NIELSEN, B., K. SCHMIDT-NIELSEN, A. BROKAW and H. SCHNEIDERMAN. Water conservations in desert rodents. J. Cell. & Comp. Physiol. 32: 331, 1948.

8. SCHMIDT-NIELSEN, B. and K. SCHMIDT-NIELSEN. Evaporative water loss in desert rodents in their natural habitat. Ecology 31: 75, 1950.

9. SCHMIDT-NIELSEN, B. and K. SCHMIDT-NIELSEN. Pulmonary water loss in desert rodents. Am. J. Physiol. 162: 31, 1950.

10. SCHMIDT-NIELSEN, B. and K. SCHMIDT-NIELSEN. Do kangaroo rats thrive when drinking sea water? Am. J. Physiol. 160: 291, 1950.

11. SCHMIDT-NIELSEN, B. and K. SCHMIDT-NIELSEN. A complete account of the water metabolism in kangaroo rats and an experimental verification. J. Cell. & Comp. Physiol. 38: 165, 1951.

12. SCHMIDT-NIELSEN, B., K. SCHMIDT-NIELSEN, T. R. HOUPT and S. A. JARNUM. Water balance of the camel. Am. J. Physiol. 185: 185, 1956.

13. SCHMIDT-NIELSEN, K. Heat regulation of small and large desert mammals. In: Biology of Deserts, edited by J. L. Cloudsley-Thompson. London: Institute of Biology, 1954, p. 182.

14. SCHMIDT-NIELSEN, K. Animals and arid conditions: Physiological aspects of productivity and management. In: The Future of Arid Lands, edited by G. F. White. Washington: Am. Assoc. Adv. Sci., 1956, p. 368.

15. SCHMIDT-NIELSEN, K. and B. SCHMIDT-NIELSEN. Water mebolism of desert mammals. Physiol. Rev. 32: 135, 1952.

16. SCHMIDT-NIELSEN, K., B. SCHMIDT-NIELSEN, T. R. HOUPT and S. A. JARNUM. The question of water storage in the stomach of the camel. Mammalia 20: 1, 1956.

17. SCHMIDT-NIELSEN, K., B. SCHMIDT-NIELSEN, S. A. JARNUM and T. R. HOUPT. Body temperature of the camel and its relation to water economy. Am. J. Physiol. 188: 103, 1957.

18. SCHMIDT-NIELSEN, K., B. SCHMIDT-NIELSEN and H. SCHNEIDERMAN. Salt excretion in desert mammals. Am. J. Physiol. 154: 163, 1948.

19. SPERBER, I. Studies on the mammalian kidney. Zool. Bidrag. Uppsala 22: 249, 1944.

20. VORHIES, C. T. Water requirements of desert animals in the southwest. Univ. Arizona Techn. Bull. No. 107, 487, 1945.

ASSOCIATE MEMBERSHIP PROPOSAL

The Council of the American Physiological Society and the Committee on Education have been concerned for several years about the number and quality of young men and women seeking a career in physiology. Other national organizations (National Research Council, American Institute of Biological Scientists, National Science Foundation and National Institutes of Health) have likewise recognized the need with respect to biology in general. The problem is a big one and many plans are being developed by many groups to solve it.

The Council believes that one concrete proposal that could be put into effect this year merits consideration by the members of the Society. It is designed to assist the next generation of physiologists - mature graduate students in biology and those just postdoctoral. The proposal would establish Associate Membership in the American Physiological Society. Those eligible for Associate Membership would be graduate students in biology at a predoctoral level, teachers of physiology and investigators in biology who have not yet had opportunity or time to satisfy the requirements for full membership.

The procedures for proposing and approving Associate Members would be the same as those for regular members and would require sponsorship by two regular members of the American Physiological Society and a favorable vote by the Council and by the Society. Associate Members would pay yearly dues of $5 to the American Physiological Society, and would have the privileges of subscribing to the Journals of the Society at reduced rates for members, and of presenting papers at the Fall meeting of the Society without the necessity of being sponsored by a full member. However, they would not be voting members of the American Physiological Society; they would not be members of the Federation of American Societies for Experimental Biology; and would not have the privilege of presenting papers at the Federation Meeting without sponsorship of a member. They would receive THE PHYSIOLOGIST.

The Council hopes that the creation of Associate Membership may aid in attracting and keeping more capable people in the field of physiology; the physicists and chemists have found it helpful in this respect in their groups. Associate Membership can provide for the younger physiologist a sense of belonging to physiology and a feeling of loyalty to the American Physiological Society in the early critical years that may determine whether he or she will remain a physiologist. It may prevent the feeling of resentment that develops occasionally from not belonging to the Society or not even being proposed for membership. It should encourage younger physiologists to subscribe to our journals and build a permanent library of them. And yet it should not destroy the incentive to do good independent investigative work so that full membership may be achieved and it should not diminish the prestige associated with full membership. Associate Members will be encouraged to acquire the qualifications for full membership.

Broadening the base of membership in this way will not crowd the Fall scientific programs because many potential Associate Members now present papers there, though often under the sponsorship of someone less directly concerned with their work. It should not overwhelm the Spring program because Associate Members would not be members of the Federation and would not be eligible to present papers without the

usual sponsorship. If a large number of Associate Members have an interest in special areas of teaching and investigation in physiology, the Council will develop special programs to encourage this interest.

Before making this recommendation for the creation of Associate Membership a study was made of the membership requirements and regulations of more than 50 scientific organizations, of previous reports to the Council of the American Physiological Society, of opinions and attitudes of physiologists expressed through the Survey of the Physiological Sciences and conferences of the National Research Council Committee on Educational Policy, of suggestions made to Dr. Louis Katz on his "President-elect tour" and to Dr. Wm. Amberson on his "Teaching Tour" which was sponsored by the Committee on Education of the American Physiological Society. In addition an ad hoc Committee met at Chapel Hill, N. C., on April 1, 1957 to formulate tentative recommendations*, which were then modified in Council discussions on April 14, 1957.

The proposal to create Associate Membership has been approved in principle by the members of the American Physiological Society at the April 1957 business meeting. However, Council wishes all members to consider this problem and propose further suggestions that might be of value to the young physiologist. The proposal in final form will be presented to the Society at the April 1958 meeting for vote. It will involve changes in the By-Laws. The important changes are contained in the following new paragraphs:

Article I. Membership

Section 1. The Society shall consist of members, honorary members and associate members.

Section 4. Associate Members. Graduate students in physiology at a predoctoral level, teachers of physiology, and investigators who have not yet had opportunity or time to satisfy requirements for full membership shall be eligible for associate membership in the Society provided they are residents of North America.

Article III. Dues

Section 1. The annual assessment on members and on associate members shall be determined by the Council and shall be due in advance on July 1.

Article VII. Standing Rules

Section 3. Election to Associate Membership. Associate members shall be proposed, nominated and elected in the same manner as full members. Associate members shall have the privilege of attending

*M. Bates (Prof. Zoology, U. of Michigan), J. H. Comroe, Jr., Chm. (Prof. Physiol., U. of Pa.), Harriet Creighton (Prof. Botany, Wellesley), H. D. Green (Prof. Physiology, Bowman Gray), D. Griffin (Prof. Zoology, Harvard), M. O. Lee, Howard Phillips (Dean Graduate School, Emory), Irvin Sizer (Prof. Biology, M.I.T.), and Paul Weiss (Rockefeller Institute).

business sessions of the Society but shall have no vote. Associate members may be nominated for full membership.

Section 4. Presentation of papers. At a spring meeting of the Society held in conjunction with the Federation meetings a member or honorary member may present orally or by title, or introduce not more than one scientific paper, except upon invitation of the Council. An associate member or non-member may present orally one scientific paper only if sponsored by a member of the Society. At the Fall meeting, a member, honorary member, or associate member may present orally not more than one paper, except on invitation of the Council.

J. H. Comroe, Jr.
Chairman of ad hoc committee

SPRING MEETING

The Spring meeting of the Society will be held in Philadelphia, April 14-18, 1958, in association with the other constituent societies of the Federation. The headquarters hotel for the Physiologists will be the Benjamin Franklin. Council and Federation Board meetings will begin on Sunday, April 13; Scientific Sessions will open at 1:30 p. m. Monday, April 14, and continue through Friday afternoon, April 18. Session rooms will be located in Convention Hall, the University of Pennsylvania and the Philadelphia General Hospital. Exhibits will be located in Convention Hall. The Placement Service will be located in the Center Building of Convention Hall.

Registration desks will be located in the three headquarters hotels (Benjamin Franklin, Bellevue Stratford, Sheraton) on Sunday from 9:00 a. m. to 9:00 p. m. and on Monday from 5:00 to 9:00 p. m. The registration desk at the Benjamin Franklin will be in the Ballroom Foyer on the Mezzanine. Monday through Friday noon, registration will be held at Convention Hall -- the hours will be from 8:00 a. m. to 5:00 p. m. Programs, abstracts and tickets to special functions will be on sale near the registration desks.

EXPERIMENTAL SESSIONS AT SPRING MEETING

Last year there were a few Physiology sessions at the Federation meetings that contained only 8 or 9 papers instead of the usual 11 or 12. The chairmen of two of these short sessions utilized the remaining time for additional discussion of the general subject of the session. These were so successful that several members requested more of these shorter sessions with announced time for general discussion. This year the program will indicate a few such sessions with time allotted for general discussion at the end.

Another suggestion to Council was to open sessions by an invited paper of 20 minutes' length. The object of such a paper would be tutorial, to state the background of the subject matter of that program and the problems as the author saw them. Council appointed a committee to select 8 or 10 topics, in which such groups of papers might be anticipated, and to select the chairmen who might preside and give such introductory papers. This will be done for the 1958 Spring meeting.

CANDIDATES FOR MEMBERSHIP

Council recommends for membership in the American Physiological Society the following 47 candidates. They will be voted on at the Business Meeting held in connection with the Spring Meeting at Philadelphia.

(1) ALEXANDER, Natalie: Asst. Prof. Physiol., Univ. Southern California.
Sponsors: D. R. Drury, W. H. Bachrach.

(2) ALTSZULER, Norman: Instr. Pharm., N. Y. Univ. Coll. of Med.
Sponsors: R. C. de Bodo, S. J. Farber.

(3) AXELROD, David R.: Asst. Prof. Physiol., Cornell Univ. Med. Coll.
Sponsors: R. F. Pitts, R. L. Greif.

(4) BARLOW, George: Asst. Prof. Clinical Physiol., Univ. of Tennessee Coll. of Med.
Sponsors: R. R. Overman, J. P. Quigley.

(5) BURLINGTON, Harold: Asst. Prof. Physiol., Univ. of Cincinnati Coll. of Med.
Sponsors: G. K. Moe, W. D. Lotspeich.

(6) BUSKIRK, Elsworth R.: Chief, Environmental Physiol. Section, Quartermaster Research and Development Command, Natick, Mass.
Sponsors: A. Henschel, H. L. Taylor.

(7) CARTER, Earl T.: Asst. Prof. Physiol., Ohio State Univ.
Sponsors: E. Ogden, F. A. Hitchcock.

(8) CHOW, Kao L.: Asst. Prof. Physiol., Univ. of Chicago.
Sponsors: J. M. Tobias, F. C. McLean.

(9) COOK, Sherburne F.: Prof. Physiol., School of Med., Univ. of California, Berkeley.
Sponsors: L. L. Bennett, I. L. Chaikoff.

(10) DETWEILER, David K.: Chr. Dept. Vet. Med. Sci., Graduate School of Med., Univ. of Pennsylvania.
Sponsors: F. H. McCutcheon, M. Reynolds.

(11) DURBIN, Richard P.: Assoc. in Physiol., Harvard Med. School.
Sponsors: A. K. Solomon, A. C. Barger.

(12) EIK-NES, Kristen B. D.: Asst. Res. Prof. of Biochem., Univ. of Utah Coll. of Med.
Sponsors: T. F. Dougherty, H. L. Borison.

(13) EVARTS, Edward V.: Chief Physiol. Section, Lab. of Clin. Sci., National Inst. Mental Health.
Sponsors: W. H. Marshall, S. S. Kety.

(14) FEDOR, Edward J.: Asst. Prof. Surg. Res., Univ. of Pittsburgh School of Med.
Sponsors: B. Fisher, W. W. Swingle.

(15) FRITTS, Harry W., Jr.: Assoc. in Med., Columbia Univ. Coll. of Physicians and Surgeons.
Sponsors: A. Cournand, W. F. Hamilton.

(16) FURMAN, Robert H.: Assoc. Prof. Res. Med., Univ. of Oklahoma School of Med.
Sponsors: D. B. Zilversmit, R. M. Bird.

(17) GOLDRING, Sidney: Instr. in Neurosurgery, Washington Univ. School of Med.
Sponsors: G. H. Bishop, W. M. Landow.

(18) GORDON, David B.: Asst. Prof. Physiol., Univ. of Miami School of Med.
Sponsors: G. C. Ring, W. G. Moss.

(19) HANNON, John P.: Res. Physiologist, Arctic Aeromedical Lab., A. P. O. 731, Seattle, Wash.
Sponsors: K. Rodahl, R. Hock.

(20) HILTON, James G.: Assoc. Prof. Pharm., Univ. of Mississippi School of Med.
Sponsors: R. V. Brown, D. R. H. Gourley.

(21) IAMPIETRO, Patsy F.: Physiologist, Environmental Physiol. Section, Quartermaster Research and Development Command, Natick, Mass.
Sponsors: D. E. Bass, E. F. Adolph.

(22) KESSLER, Richard H.: Instr. Physiol., Cornell Univ. Coll. of Med.
Sponsors: R. F. Pitts, R. L. Greif.

(23) KITZINGER, Charlotte: Med. Officer, Naval Med. Res. Inst., Bethesda, Md.
Sponsors: E. F. DuBois, K. S. Cole.

(24) KRAMAR, Jeno L.: Assoc. Prof. Pediatrics, Creighton Univ. School of Med.
Sponsors: C. M. Wilhelmj, J. R. Johnson.

(25) KUPFER, Sherman: Asst. Prof. Physiol., Cornell Univ. Coll. of Med.
Sponsors: R. F. Pitts, C. J. Wiggers.

(26) LANE, Ardelle C.: Asst. Prof. Physiol., Northwestern Univ. Dental School.
Sponsors: A. C. Ivy, S. C. Harris.

(27) MALIS, Leonard I.: Asst. Attending Neurosurgeon, Mount Sinai Hosp., New York City.
Sponsors: M. B. Bender, K. H. Pribram.

(28) MERRICK, Arthur W.: Asst. Prof. Phsyiol., Univ. of Missouri Medical Center.
Sponsors: B. A. Westfall, D. K. Meyer.

(29) MIXNER, John P.: Prof. Dairy Husbandry, Rutgers Univ.
Sponsors: J. H. Leathem, P. D. Sturkie.

(30) PALMES, Edward D.: Assoc. Prof. Industrial Med., N. Y. U.
Sponsors: L. W. Eichna, C. R. Park.

(31) PAYNE, Loyal C.: Assoc. Prof. Vet. Physiol. and Pharm., Iowa State College.
Sponsors: E. A. Hewitt, H. E. Essex.

(32) PHILLIPS, Hugh J.: Asst. Prof. Physiol. and Pharm., Creighton Univ. School of Med.
Sponsors: J. R. Johnson, C. M. Wilhelmj.

(33) PORTER, John C.: Asst. Prof. Physiol., Univ. of Texas-Southwestern Med. School.
Sponsors: R. W. Lackey, J. C. Vanatta.

(34) PRATT, Elmer B.: Asst. Prof. Med., Univ. of Colorado School of Med.
Sponsors: H. M. Hines, J. H. Holmes.

(35) REEVE, Ernest B.: Assoc. Prof. Med., Univ. of Colorado School of Med.
Sponsors: M. Gregersen, J. H. Holmes.

(36) ROSE, John C.: Asst. Prof. Med. and Clinical Instr. Physiol., Georgetown Univ. School of Med.
Sponsors: H. L. Conn, Jr., C. F. Morgan.

(37) ROSS, Benjamin B.: Asst. Prof. Physiol., Univ. of Oregon Med. School.
Sponsors: J. M. Brookhart, H. Rahn.

(38) SCHREINER, George E.: Asst. Prof. Med., Georgetown Univ. School of Med.
Sponsors: H. W. Smith, L. G. Wesson, Jr.

(39) SODERWALL, Arnold L.: Assoc. Prof. Biol., Univ. of Oregon.
Sponsors: B. T. Scheer, H. Krueger.

(40) SPIKES, John D.: Prof. Experimental Biol., Univ. of Utah.
Sponsors: R. B. Harvey, L. S. Goodman.

(41) STARK, Lawrence: Instr. in Neurology, Yale Univ. School of Med.
Sponsors: C. N. H. Long, D. L. Kline.

(42) TERZUOLO, Carlo A.: Fellow Nat'l. Multiple Sclerosis Soc., Walter Reed Army Inst. Res., Washington, D. C.
Sponsors: R. Galambos, M. G. F. Fuortes.

(43) THOMAS, Garth J.: Assoc. Prof. Psychology, Univ. of Illinois Coll. of Med.
Sponsors: L. G. Abood, W. D. Neff.

(44) THOMSON, John F.: Assoc. Scientist, Argonne Nat'l Lab.
Sponsors: D. E. Smith, A. M. Brues.

(45) TOWE, Arnold L.: Asst. Prof. Physiol. and Biophysics, Univ. of Washington School of Med.
Sponsors: H. D. Patton, T. C. Ruch.

(46) WHITNEY, John E.: Asst. Prof. Physiol. and Pharm., Med. School, Univ. of Arkansas.
Sponsors: L. L. Bennett, S. Roberts.

(47) YU, T'sai-fan: Assoc. in Med., Columbia Univ. Coll. of Physicians and Surgeons.
Sponsors: R. W. Berliner, T. J. Kennedy, Jr.

SOME STATISTICS ON GRADUATE STUDENTS

Taken from NSF Report 57-17 on Graduate Student Enrollment and Support in American Universities and Colleges in 1954

Some 516 resident graduate students of physiology were located in 66 departments in 35 States and D. C., an average of 8 per department; in addition, 51 special students were reported, a relatively large number for a biological science. Over half the national enrollment was in Illinois, California and New York.

A large proportion of the degrees awarded during 1953-54 were doctorates (53%), although the proportions of students enrolled full-time (70%) and in advanced years of study (60%) were slightly lower than among all students of biological sciences.

Sixty-eight per cent of physiology students received some type of support, half from institutional and half from non-institutional sources. Twenty-five per cent of resident students were teaching assistants, 10% fellows, and the largest group, 33%, research assistants (2/3 of whom were working on Federally sponsored projects). The Federal Government supported relatively more students of physiology than of any other biological science with as large an enrollment.

SOME COMPARISONS

Discipline	Degrees Conferred 1954		Enrollment 1953 - 1954	Number Partially Supported	Average Stipends			
	MS	PhD			Average	Teaching Assistant	Research Assistant	Fellow
Physiology	93	85	516	352	1440	1315	1560	1590
Biochemistry	105	145	777	588	1590	1485	1635	1675
Pharmacology	--	--	217	214	1740	1585	1690	1890
Bacteriology	242	131	815	465	1330	1170	1490	1585
Anatomy	--	--	236	180	1440	1410	1435	1720

Roles for Senior Physiologists

By D. B. Dill

This topic was discussed at a special session of the meeting of The American Physiological Society held at the State University of Iowa, 4-6 September 1957. As Chairman of the Society's Committee on Placement of Senior Physiologists, I presided and reviewed recent events pertinent to the topic. Last January the other members, Fenn, Hamilton and Landis, joined me in seeking the advice of 175 senior members of the Society. We asked them what forms of professional activity best utilize the capabilities of senior physiologists. The speakers at the special session dealt with some of the topics emphasized by the 82 members who responded to our inquiry.

Are there teaching opportunities in colleges for retired physiologists? E. A. Hewitt, Iowa State, explored this question through an inquiry addressed to 24 Iowa colleges. While the majority of the 23 replies were unfavorable, 6 opened the door to this possibility by expressing willingness to consider hiring retired physiologists for teaching or research. Horace W. Davenport, Head of the Department of Physiology at Michigan, discussed opportunities for professors continuing research after becoming emeritus. He described the practice at a few institutions and pointed out some of the difficulties "well known to us all" that prevent establishing a rigid policy.

Fred R. Griffith, Jr., Professor Emeritus, Buffalo, had prepared a survey of retirement policies in medical schools. Griffith was unable to present his paper; in his absence his findings were presented by W. F. Hamilton. From 81 replies to 94 inquiries the following facts emerged: 7% have no retirement plan or do not enforce one; 27% have retirement at age 70 or options making this mandatory; 16% have retirement at age 68 or options making this mandatory; 7% have retirement at age 67 or options making this mandatory; 45% have retirement at age 65.

Space and support are provided for those who desire them in many cases although allocation of space may be left to the new head of the department and support may depend on getting grants from outside sources. In some cases it is expected that the retired professor will move to another department. In a few cases neither space nor support is provided.

T. L. Patterson spoke on research opportunities in marine biological laboratories. For those retired physiologists who have suitable research interests, may such laboratories have ample unused research facilities for nine months of the year.

Until recently the State Department has had a science attache at a few of the major embassies. W. H. Forbes, the last physiologist holding such an appointment, described what was expected of him. The job requires wide scientific knowledge, tolerance, understanding of human nature, ability to speak the language, scientific integrity and ability to make friends. Forbes urged that a strong Washington office be set up

* Reprint of an article appearing in Science.

by the State Department, that attaches be appointed for two years and that there be two scientists at each of six or eight posts with appointments staggered to give a one-year overlap.

It had been hoped that James A. Shannon (National Institutes of Health) would discuss opportunities offered senior scientists by Government. In his telegram explaining his inability to attend he emphasized two points: a) First, there is an established pattern in government wherein senior scientists have served in the past and will continue to serve as senior scientific advisors. The number of these positions is limited but the service these individuals render is invaluable. b) Second, he pointed out the availability of Public Health Service grant funds for support of senior scientists. As in the past, the Public Health Service will accept research grant applications from individuals beyond the age of formal retirement from their academic posts. The university concerned must support the application and provide adequate physical facilities for the program. Such a research grant can contain the salary of the principal investigator to an extent that the total salary derived from retirement income and the research grant is equivalent to that of a comparable full-time research worker.

Charles C. Chapple, Veterans Administration, expressed the interest he had in the session in a letter to Dill reading in part as follows:

"Each Veterans Administration Hospital is autonomous in its selection of employees and consultants, and on this account interested individuals should apply directly to the manager of the hospital of his choice. Interested individuals can write the Assistant Chief Medical Director for Research and Education for information about the type of research going on in any particular hospital as a preliminary step if any would care to do so, or the applicant can, of course, learn this by calling personally on the hospital manager. There are research laboratories in all the hospitals affiliated with medical schools and in many of those which are not. The interests in these hospitals vary widely but in many there is need for assistance in physiology, pharmacology and biochemistry in particular."

Nearly 12,000 retired college and university faculty members are listed in a registry maintained by Constantine Panunzio. It includes many scientists, including a few physiologists. He has had good success in placing retired scientists, mathematicians and engineers. His address is Dr. Constantine Panunzio, Director, The Emeriti Employment Registry, Box 24451, Los Angeles 24, California.

The Autumn issue of the AAUP Register, 1957, announces that there will soon be set up in Washington, D. C. a registry of retired faculty members:

"The Ford Foundation, on July 1, 1957, made a grant of $205,000 to the American Association of University Professors and the Association of American Colleges for the establishment and administration, during a five-year period, of a national register of retired college and university faculty members available for academic positions. The Council, in November 1955, had approved sponsorship of such a register by the American Association of University Professors (Bulletin, Vol. 42, p. 183), and the two Associations later submitted a joint proposal to the Fund for the Advancement of Education, established by the Ford Founda-

tion, for such a register as a service to higher education in a time of growing need for faculty personnel."

The 82 physiologists who replied to our original inquiry made many penetrating and wise comments. The following three paragraphs quoted from A. N. Richards' reply sum up the thoughts of many: -

"... provision for useful and satisfying post-retirement years for a scientist is a highly individual matter and can be settled satisfactorily only with a background of intimate knowledge of the human and scientific makeup of departments in which he might hope to find productive happiness.

"It seems to be the almost universal aim of foundations, private and governmental, to discover and promote youthful promise. To discover and promote senescent ability and promise doesn't offer much allure. But if young scientists, thoughtful about their long future, are obliged to witness their older models cast up on the beach, long before they have the privilege of dying, recruitment of some of the good young minds may meet interference.

"It seems to me that, connected with any of the three suggestions you have put forward, or the vague and probably unfeasible thoughts which I have tried to express, there must be escape clauses, admittedly difficult to implement or even visualize -- escape for the man; escape for the institution."

Finally President Louis Katz congratulated the members of the committee and the participants in the session. In his tour as President-Elect many physiologists expressed to him their appreciation of the activities of the committee: it has helped some physiologists and it has strengthened physiology.

AMATEUR MUSICIANS AND AFRICIONADOS

The Federation's Amateur Chamber Music Players propose to congregate again at the Philadelphia meeting. Anyone interested in participation or knowing of prospects who will attend the 1958 meeting should inform W. E. Cohn, Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., who is acting as impresario and general manager.

The picture on the back cover of this issue of The Physiologist is that of the front of Beaumont House, Federation Headquarters, 9650 Wisconsin Avenue, Washington, D. C. The Central Office of the American Physiological Society is located in this building.

FEDERATION PLACEMENT SERVICE

The Placement Service is designed to meet the needs of employers and of individuals desiring positions in the fields of the Federated Societies. Its activities are:

1) Listing positions, fellowships and exchanges available in academic, industrial and governmental institutions, foundations and societies
2) Listing applications for positions from qualified individuals, chiefly at the professional level (Ph. D. or equivalent)
3) Circulating
   a) Quarterly lists of applicants with brief summaries of their qualifications
   b) Semiannual lists of available positions, and
   c) Annual lists of available fellowships and exchange positions

Lists will be issued on a subscription basis, with an annual price of $15.00 to include all lists published in a calendar year. Single copies of the lists of candidates are $10.00 and of lists of positions $5.00. A single copy of the fellowship list will be sent without cost to any member of a constituent Society upon written request. To others the price of this list is $2.00. Lists of candidates are prepared February 1, May 1, August 1, November 1; lists of positions March 1 and September 1; and the list of fellowships October 1.

It is expected that the lists will be issued chiefly to the heads of departments of universities, directors of research or personnel managers of industrial or governmental agencies. Individuals may subscribe but it is emphasized that wherever possible it will be to their advantage to utilize the subscription of their department or agency.

Lists of available personnel and of available positions will be grouped by the fields of the six member Societies. All groups will be included in each issue, since many candidates have qualifications in two or more fields, and since some positions may utilize training in more than one field. The list of fellowships will include all fields.

At the Annual Meeting of the Federation, the Placement Service registers applicants and employers and schedules interviews requested by employers. At the Philadelphia Meeting applicants may register from 1:00 to 5:00 p.m. on Sunday, April 13, and 8:15 a.m. to 5:00 p.m. Monday through Thursday. Employers may register from 8:15 a.m. to 5:00 p.m. Monday through Thursday. Interviews will be held through Thursday.

Lawrence Joseph Henderson

Born June 3, 1878, died February 10, 1942

Some Remarks Made at the Respiration Dinner,
Chicago, April 17, 1957

By Dickinson W. Richards

It is a defect but also a privilege of age to look backward instead of forward. This evening I am going to take advantage of the freedom traditionally given to speakers on this occasion, and talk for a few minutes about the most stimulating and exciting personality that it has been my privilege to know, Professor Lawrence J. Henderson.

This is not an easy task. There is nothing more difficult than to bring to life again, vividly before us, a person who has died, whether a week or a month ago, or a thousand years ago. This general conclusion came upon me in melancholy fashion, as I thumbed through the journals of 1942 and 1943, looking for obituary notices; noting the finality, the extraordinary finality, of that event when a man's name moves in the indices from the list of "Authors" to the list of "Subjects"; this impression of finality exceeded only by the even stronger impression of deadness that pervaded most of the obituaries themselves, when I had finally found and perused them.

I am not even too well fitted to give this account. There are others who could do much better, some perhaps here now. I saw a good deal of Professor Henderson in the decade from 1922 to 1932, and he helped me enormously in my early experimental work; but I never worked in his laboratory. I knew him, even then, more through the eyes and the accounts of my friend and classmate, Cecil Murray, -- Mike Murray, as he was known -- who worked with him very closely indeed, travelled and spent summers with him, in the years 1922 to 1927, when Henderson was bringing together the integration of knowledge of the physical chemistry of the blood. More of this later.

Well, then, what was he like, "Professor L. J."? He was a stoutish man of middle stature, usually wearing a red necktie and a brown tweed suit. He had light thinning red hair and a red beard, graying as the years moved on. His eyes were wide and very blue, his cheeks pink, his expression in repose a little surprised, in his earlier years even a

little cherubic. His voice was high, his diction precise. He spoke always deliberately, and after thinking; his most devastating remarks coming forth calmly, with an expression half serious, half amused. He dislike physical activity, except walking. Among the guiding principles of his life, I would say, were to protect his own time and to keep away from people who bored him. He used to claim that he was constitutionally lazy, that he liked to think so to avoid doing things. This remark was of course something of a pose. His penetrating and restless mind was never still. He read and studied tremendously, especially science and philosophy, less so in literature and history. He was never a universal reader, such, for example, as his friend of later years, A. N. Whitehead.

More than anything, he enjoyed good conversation in good company. Give him a few congenial friends, an excellent dinner, and a judiciously selected wine, and he would indeed expand. He was very fond, almost inordinately so, of a good epigram, a fine generalization. He liked to characterize a man in a single phrase. A certain earnest German physiologist L. J. dismissed as "a good third-rate man". James Gamble, to whom he was devoted, he said was "pathologically modest". He didn't like Henry Fairfield Osborn, the distinguished but slightly stuffy geologist and museum director. "Fairfield Osborn," said L. J., "is the perfect example of the man who became famous because he thought he was". I will give you a few more of these aphorisms later.

Cecil Murray and I used to debate who it was that the Professor most looked like. It seemed to me he was quite a bit like Socrates, the Socrates of those early dialogues, when he was young and lively, poking fun at aged philosophers, and straining the wits of young ones. Murray said Professor L. J. looked like the younger portraits of Henry the Eighth. Perhaps he did, but the resemblance went no further. He had, no doubt, an equal intellectual force with the great Tudor king, but nothing whatever of his rascality of character. It may as well be said now as later that in spite of his complete freedom of mind, in personal behaviour Henderson was always most courteous and considerate. That fine old Jeffersonian phrase, "a decent respect for the opinions of mankind," applied well to his manner of life.

I regret that this account now seems to be slipping into the standard obituary line, in spite of myself. It will brighten up in a minute or two. I have to give, however, just a few items of his curriculum vitae.

He was born in Lynn, Massachusetts June 3, 1878. He entered Harvard at 16, wrote an essay for a prize on the chemical theories of Arrhenius, than went through medical school, then to Europe for two years in Hofmeister's laboratory in Strasbourg. Walter Cannon, (1) in his memoir on Henderson, says of this period, "There is question as to whether he received any formal advantage from his experiences there; an associate has testified that he was prone to wander about the laboratory and converse and theorize with other advanced students." -- Can't you just see him? I don't know who this associate was; he sounds a little ponderous. What Professor Henderson used to say to Murray and me about these earliest years in Europe was that he had a wonderful time; and incidentally that it was during his first summer abroad that he grew his beard; a rather notable accomplishment, perhaps, in view of the vast renown that this brilliant appendage was to achieve in later years.

Back to Harvard, as Lecturer in Biological Chemistry, in 1904. The next twelve years were immensely active. There is no need to review here the chemistry and physiology of his far-reaching concepts of acid-base balance and neutrality regulation in living organisms, --even if I could do this adequately, which I cannot. The point that I should like to make is the extent to which Henderson pursued all aspects of this general idea, philosophical as well as scientific. Like William Harvey, "On these and other such matters," he "pondered long and deeply". Out of this came Henderson's two philosophical essays, The Fitness of the Environment, published in 1913, (2) and The Order of Nature, four years later. (3) It has always surprised me that these two essays are not more widely known. They constitute a precise description of Henderson's scientific philosophy, and incidentally provide a valuable background for his later physiological writings. The first is better known than the second: it consists, essentially, in an examination of the properties of the elements hydrogen, oxygen and carbon, and particularly their combinations, water and carbonic acid, and the demonstration that it is by the unique properties of these substances that living beings can be formed and can exist. It is a logical proof of the adaptability of matter to life, and life to matter. In his second volume, he moves further into philosophy and boldly attacks the problem of teleology, reaching the conclusion that the functional relationships found in nature, in living organisms, cannot be due to mere contingency; are ordered, or evolutionary and therefore necessarily teleological. This, obviously, is teleology as a general philosophic principle, and not as merely a handy explanation for small individual events. In the course of this work, Henderson studied intensively the papers of J. Willard Gibbs, whose ideas on systems, phases and the like were important in his subsequent elucidation of the complex system of the physical chemistry of the blood.

In 1917 came the war. In that far-off undisillusioned time, everyone, from the highest to the lowest, was moved to do everything or anything he could that might save the world for democracy. Henderson left biochemical theory, and set himself, of all things, to cure the troubles of so-called "ropey" bread. I do not know any details of this. Henderson was not too good an experimenter and apparently not at all a good baker. Mike Murray used to tell me tales of horrible smells and glutinous messes that erupted out of the laboratory during this adventure. I do have the record of the publications that eventually issued. One I note in particular, entitled "The Influence of Electrolytes on the Viscosity of Dough." The authors were Lawrence J. Henderson, Edwin J. Cohn and Wallace O. Fenn. History also seems to record that this notable triumvirate broke up rather hastily when the war was over. Cohn delved ever deeper into the mysteries of proteins, Henderson retired to his study, while Fenn fled to the open air, with the greatest benefits thereafter, to us and to all science.

Right after the war began Henderson's second great era of discovery. Even during his somewhat Laocoan struggles with ropey bread, his mind had evidently been moving along its previous path, and the stunning series of papers, beginning again in 1920, moved ahead rapidly.

The prime event, apparently, that set this whole development in motion, was Henderson's appreciation of the full significance of the interaction of oxygen and carbon dioxide in blood. He wrote later two very searching comments on this, as follows:

"To those, "he wrote, "who have not themselves experienced

that state of bewilderment which is the usual condition of the investigator, it must seem strange that the physiologists who were studying the respiratory function of the blood should not have drawn from the discovery of the variation of oxygen saturation with carbon dioxide pressure the conclusion that, since carbon dioxide influences the oxygen equilibrium in blood, oxygen must influence the carbon dioxide equilibrium." And, again, "In studying the interaction between oxygen and carbon dioxide, it is of the first importance not to regard the change in one substance as cause and the change in the other as effect. If we think of our terms mathematically as variables and functions, the difficulty does not arise." This is a general statement that could well be applied more widely.

At all events, once Henderson was able to set this equilibrium upon a single diagram, the basic integration went forward rapidly. As early as 1921, when he lectured in France, the general outline of the blood nomogram had been devised.

By extraordinary good fortune, Donald D. Van Slyke in New York was just then fully under way in his investigation of the distribution and movement of electrolytes between red blood cells and plasma. Henderson and Van Slyke agreed to collaborate. There have probably been few times in scientific history when so distinguished a group of first-class biochemists and physiologists, voluntarily and without ulterior pressure during times of peace, collaborated together in a common effort. This went on for more than five years. In Van Slyke's laboratory were such men as Austin, Cullen, Stadie, Hastings, Wu, Murray, Heidelberger, McLean, Sendroy; and in Henderson's, Dill, Bock, Adair, Murray for a time, later Talbott, Forbes, Johnson - to name only a few.

Van Slyke's great integration on the electrolytes of blood was published, with Wu and McLean in 1923, and this formed the second of the two foundation pillars in Henderson's final work. I won't go into any more detail on this.

In another and very pleasing phase of Henderson's career, the other, the respiratory gas aspect, was approaching completion. Perhaps the most interesting, certainly the most imaginative, of the successive papers on blood as a physicochemical system was number three, by Henderson and C. D. Murray, entitled "Deductions concerning the Capillary Exchange." Henderson and Murray both spent the summer of 1924 in Europe, and were together for several weeks in a small village in the French Alps. Here they discussed the basic problem of diffusion, the rates of exchange of respiratory gases in the lungs and in the tissues. The small inn, overlooking the mountains, where they discussed these matters, they decided to name "the Claude Bernard Laboratory," and the paper in the Journal of Biological Chemistry in 1925 duly records that the work proceeded from the Claude Bernard Laboratory, Nevache, France.

The following year Murray, and his friend Will Morgan, were in Barcroft's laboratory in Cambridge. Henderson joined them in the spring, and they put together the paper entitled: "Oxygen Exchange, Blood, and the Circulation: A Coordinated Treatment of the Factors involved in Oxygen Supply on the Basis of the Diffusion Theory." In this paper the dynamics of the circulation were added to the synthesis.

I was visiting Murray in Cambride at about this time and strove

to read and master the paper as it was written. It was rather hard going. I ventured to suggest to the Professor that some readers might appreciate a little fuller explanation in some places. I do not remember exactly his reply, but it was something to the effect that the language of mathematics does not require unnecessary detail. I do remember that I had nothing more to say on this subject at that time.

During this whole period, the group of physiologists in Boston under Dill and Bock were actively pursuing their experiments on the respiratory functions of the blood. As everyone knows, almost all of Henderson's normal nomogram was derived from the blood of A. V. Bock, a considerable part from arterial samples. Nomograms were constructed also of anemia, nephritis, diabetic coma, congenital heart disease, and so forth. Extensive studies were carried out in varying degrees of work. Cardiac output was measured by an indirect method. At one point, hearing that direct right heart punctures were being done in Germany, Bock thought that he might try this, too, on himself to obtain mixed venous blood. Henderson got wind of this, and marched into the laboratory. "Arlie," said he, "are you thinking of directly puncturing your own heart?" Bock said yes, he was. "Arlie," said Henderson, "I forbid it, "and he walked out. This tale I know is true because the Professor told it to me himself, in just these words.

What must have been the true climax of his life came in 1927, when he was invited to give, in the fall of that year, the Silliman lectures at Yale. He threw himself into this effort with tremendous energy, bringing together into a connected discourse this entire fabric of the physiology of the blood. The lectures were given, he arranged them for publication in his great classic, Blood (4); then with this done, he got on a steamer and sailed for England. I was in London that year working with Dale, and I met him on his arrival. He seemed tired, and said he was utterly exhausted after these months of work, and for a while didn't want to do anything. He soon brightened up, however, and began to look up his friends. I want to say just a few words about Henderson and his friends in England; then speak briefly about Henderson as a teacher, and then I will be finished. There were, of course, many other aspects of Henderson's many-sided personality, particularly those connected with his life-long associations and his profound influence at Harvard. These we will have to pass over.

Henderson knew very well the leaders in both the British and the Scandinavian schools of respiratory physiology. He held the elder Haldane in great esteem, admired Dale, A. V. Hill, Starling, and Cushny, and was devoted to Joseph Barcroft. Each of these two knew and enjoyed the other's peculiarities. Keith Cannon has a story which, if it isn't true, should be. It seems that Barcroft was doodling with a pencil one day on a piece of log paper, happened to plot out some points of a CO_2 dissociation curve, to find that they fell precisely on a straight line. Entertained by this, he dashed off a letter to Henderson and told him about it. In due course a reply came. "Dear Barcroft," it read, "By intellectual processes of a low order, you have arrived at a conclusion of some importance."

Then there is George Pickering's story of Henderson's remark about A. V. Hill. This is a bit sharp - Henderson's criticisms could be quite unsparing - yet with no malice. "A. V. Hill," said Henderson, "is a remarkable mathematician: He can construct a formula that will

fit any set of data, however erroneous."

Now as to Henderson as a teacher. It was a somewhat formidable thing to get started with the Professor on a scientific subject. Sidney Burwell has said that every time he ventured to express an idea to L. J., the latter would reply, "Why yes, obviously, "and there the thing would stop.

Henderson himself used to say, "I have just one procedure with my students: I neglect them. "As he knew very well, this was partly true, but very considerably not true. What would happen was something like this. You would work and strive to put your experimental ideas together, then go to the Professor and tell him about them. He would then either decapitate your entire brain child in a single whistling sentence, or else take about three more sentences to put your ideas in order for you, and you would come back and start to work. Then after a year or so you would go back to him again with what you had done; and again with great kindness - though with still the same unsparing critique - he would take your work apart. If there was anything left, after he finished with it, you would feel elated and go back and try some more.

But discussions of actual work in progress were but a small part of what Walter Cannon has well termed Henderson's "pervasive kindness" towards his younger associates. You could come to see him at almost any time, at No. 4 Willard Street, Cambridge, or at Morgan Center, Vermont. A visit was always a leisurely and pleasant occasion, with talk about all sorts of subjects, and with no evidence of other appointments, on his part, or time limits set. He would himself in his travels look you up when he came by, whether in New York, or London, or on the Continent; he always seemed to know your whereabouts.

How can one characterize, in a final work, this man who in the scientific domain has so profound an influence upon the thought of his own time, and of future times, and for whom personally one held so deep an admiration and affection? Thomas Carlyle, at the end of his essay on Samuel Johnson, had the perfect closing phrase: "Brave old Samuel, "he wrote, "ultimus Romanorum"; expressing at once his respect and affection for the man, his deference to the great Age that had gone by. But L. J. Henderson would not care a pin for this sort of tribute. He would probably smile and deflate the whole business in one word. His own evaluation, in a report to his college class 25 years after graduation, is simpler, more modest, yet no less effective (1). The satisfactions of his life, as he there described them, were these: search for new knowledge and "occasional success in the quest"; personal association and friendship founded on common interest with men at home and abroad; and "now and then the possibility of helping a younger man on his way."

REFERENCES

1. CANNON, W. B. Biographical Memoir of Lawrence Joseph Henderson. Washington: Nat. Acad. Sci., 1943.
2. HENDERSON, L. J. The Fitness of the Environment. New York: Macmillian, 1913.
3. HENDERSON, L. J. The Order of Nature, An Essay. Cambridge: Harvard, 1917.
4. HENDERSON, L. J. Blood: A Study in General Physiology. New Haven: Yale, 1928.

ON INTEGRATED TEACHING

From R. D. Tschirgi's discussion at the Refresher Course, 1957 Fall Meeting, Iowa City, Iowa

The words integrate and correlate have become a sort of Pandora's Box out of which springs a little hope accompanied by much pedagogic disaster. Is not the ideal course structure primarily dependent upon the talent and enthusiasm of the teacher, and should it not be tailored to his unique approaches for developing within the student the capacity to perform his own integration? "Chacun a son gout," and the successful technique for one instructor may result in student revolt for his colleague. Should we not concern ourselves more with the teacher; with providing him the time and incentive to increase his ability to communicate integration? Instead of twisting curricula into tighter and tighter circles until the individual instructor has lost all freedom of organization in a monumental web of integrated feedback, ought we not instead to cultivate teachers of greater breadth? Rather than grind all disciplines into a homogeneous mass to be consumed like porridge from a common bowl, is the intellectual meal not more exciting if each flavor is allowed to provide its individual piquancy at the appropriate moment?

And is not each instructor, hopefully, a wellspring of individuality who can carry his students through canyons of thought and valleys of discovery, over rapids of excitement and pools of contemplation known only to him? In the end all students will have experienced the thrills of intellectual river passage, but each will have a different story to tell and each will develop more novel approaches to his problem. And where is integration? The most miraculous of all discoveries is certainly the most difficult and requires the longest journey. It cannot be achieved by contiguity of lecture hours or weekly staff meetings or by labeling courses with common numbers. It can only be achieved by the student himself who follows his river farther and farther, realizing that at every fork others are joining him; that the disparate mountain streams passing through their various channels merge into broader and broader vistas of understanding until finally the ocean of truth lies revealed before him.

Educational Activities in the American Physiological Society - Past and Present

By E. F. ADOLPH

Chairman, Committee on Education

The following paragraphs review the organized efforts in the Society to deal with matters of education and teaching in physiology. These efforts do not extend back very many years but it may be of interest to trace briefly their beginnings.

In the fifty-year History of The American Physiological Society (1), published in 1937, no mention of any educational matters is found. Whether any aspects of teaching or related subjects were discussed in early Council meetings is not known.

In 1945 the first Survey of Physiology was authorized by the Council in order to assess current changes and immediate prospects of physiology and physiologists. The Survey Committee (Boyd, Comroe, Dow, Adolph), which discussed its findings in a special Society session (2), came to realize that changes in educational activities were uppermost in the thoughts of American physiologists. Of the various comments and suggestions which came to the Committee, the topic which drew the largest number of comments on 1000 questionaires (more than 250 out of a total of over 600 comments) was the teaching of physiology (3). A number of respondents suggested that the Society should undertake a thorough investigation of the teaching of physiology. Some stressed the need for teaching of fundamental principles, often as a part of general education. Others suggested that an opportunity should be given for the discussion of broad and technical aspects of the teaching of physiology at the Society's meetings. Several features of the training of future physiologists were also commented upon.

Of the various Committee recommendations that resulted, those which had to do with the teaching of physiology appealed to the Council as requiring most immediate action. Accordingly, the Council appointed a second committee, entitled The Committee on Teaching Problems in Physiology (Gerard, Irving, Landis, Weiss). This Committee examined the educational aspects of physiology in North America. As a result of its discussions it conducted a public session on the topic, "Perspectives in Physiological Education" (4). This session, which was attended by 250 individuals, concluded with a general discussion, and a questionaire was distributed asking certain specific questions of those present. Of all the questions asked, the one which received the highest percentage of affirmative votes was "Should APS become actively concerned with the problems of physiologists by creating a committee on educational matters?" Another set of questions had to do with more detailed possibilities; one was "Should special studies be undertaken of current teaching practices and trends?" and another was "Should a regular sectional meeting on teaching be set up at annual meetings?" Both of these questions received highly affirmative votes. As a result of these discussions and questionaires there seemed to be no room for doubt concerning the interest of physiologists, both Society members and non-

members, in the active study of educational matters.

No specific actions appear to have been taken until 1950, when the Council authorized the organization of the first teaching session.

Spring Teaching Sessions

Teaching Sessions at Spring meetings have been a regular feature of the annual Society programs, beginning with 1951. Their object was to offer a forum for communication and discussion of teaching problems and materials. Communications offered to the Teaching Session were exempted from the stricture that a member may not present more than one paper. The first program was composed of papers voluntarily submitted by members, and created considerable enthusiasm among the more than 200 people who attended.

The subsequent teaching sessions did not call forth very many spontaneous offerings from members. Anticipating this, the Council appointed a chairman to solicit contributions each year; after 1953 the Committee on Education took over the nomination of chairmen for the annual teaching sessions. The following (5) is a list of the sessions which have been held, under the titles and chairmen indicated.

1951	Principles and Methods	Davenport
1952	Medical Physiology	Comroe
1953	Teaching of Physiology	Dill
1954	Teaching of Physiology	Prosser
1955	Aims of Laboratory Instruction	Field
1956	College Physiology	Prosser
1957	Graduate Students in Physiology	Adolph

Each session was attended by 150 to 250 individuals and considerable discussion resulted.

Committee on Education

In 1953 the Council voted that a Committee on Education should be organized. The motives for organization of the Committee were chiefly that without a committee no specific educational projects were promoted. The Committee as organized consisted of Amberson, Comroe, Prosser and Adolph; in 1957 Martin was added to it. When the Committee first met, a variety of desirable activities were considered, and the following objectives were framed: a) promotion of discussion among physiologists interested in teaching; b) stimulation of effort and experimentation in teaching; c) recognition of teaching interests and activities; d) analysis of methods of instruction; e) continuation of physiologists' education; f) exchanges of teaching materials; g) dissemiation of vocational materials. Most of the immediate thought was directed toward the promotion of teaching activities at the meetings of the Society. Only later were projects developed outside of the Society meetings.

Brochure on Careers in Physiology

As its initial activity the Committee prepared a brochure for distribution to vocational counsellors. This was approved by the Council and its distribution, at the Society's expense, was begun in December 1954. Though inadequate for the purpose, it has been sent to over 2000

vocational counsellors and students who have requested copies. Plans were made for a more adequate, attractive brochure, but to date no further description of careers in physiology has been issued.

Refresher Courses

Dr. Comroe offered to organize a refresher course in order to present techniques and subject matters in a small segment of physiological teaching. Arrangements were made for 1-½ days of sessions on "Pulmonary Physiology" just before the fall meeting of September 1954. An expected attendance of 65 was actually doubled by those who came to the sessions. A model was set in the informality of the course and in its emphasis upon presentation and attitudes rather than upon subject matter per se (6). The Council of the Society underwrote whatever incidental expenses might be incurred by those who conducted the course. Other individuals aided in the first refresher course (Rahn, Fenn, Fowler, and Mead).

Subsequent refresher courses (7) have been conducted as follows: 1955, Davenport, assisted by Wilde, Mayerson and Wasserman, on the topic "Teaching of Fluids, Electrolytes and Acid Base;" 1956, Burton, assisted by ten individuals, on the topic "Teaching of Elementary Hemodynamics to Medical Students;" 1957, Brookhart, assisted by Mountcastle, Nastuk and others, on the "Teaching of Neurophysiology of the Central Nervous System." The refresher sessions have been vigorously attended, usually occupying an entire day before the start of the fall meeting. They appear to have furnished to physiologists generally a basis of broad discussion of subject matter and of presentation methods. So far they have taken up topics which are taught in medical schools in physiology.

Workshops for Teachers of College Physiology

Dr. Prosser explored the possibility of holding a workshop and the National Science Foundation supported such a workshop in the summer of 1955. The aim was to bring together for a period a cross-sectional group of college teachers who would compare notes on teaching problems and materials. Prosser organized the first workshop, which lasted 2 weeks, was held in Connecticut. and was attended by approximately 40 selected teachers of college physiology. The discussions at the workshop sharply pointed to immediate programs for the Committee's further activities, and the items which have been undertaken are chiefly those which were emphasized at the workshop.

The second workshop, in 1956, was organized in Wisconsin by Ronkin and followed the tradition set by the first workshop. In 1957 two workships were organized, one by Scheer in Oregon and the other by Morrison in North Carolina. All were supported by the National Science Foundation at a cost per workshop of approximately $7000. College teachers who participated came from a variety of institutions, and in many cases learned for the first time that their problems of scientific and administrative work are shared by most persons who teach college biology. A subcommittee on workshops consists of Prosser and Ronkin.

Summer Traineeships

Traineeships which would enable college teachers of physiology

to spend summer periods in research laboratories were found desirable and the National Institutes of Health offered support for them. Accordingly, Amberson planned and publicized a modest traineeship plan for the summer of 1956. Suitable information about the plan was distributed to 300 teachers of college physiology. Each candidate for a traineeship was asked to select from a list of 14 host institutions one or more in which he would like to work, and arrangements were made to connect each successful candidate with his chosen host. Twenty-eight completed applications were received, from which eleven trainees were chosen, and $10,000 was allocated to their support. The Committee on Education acted as a Committee of Selection, and in doing so was much impressed with the need for further traineeships, since worthy candidates were deferred. Six candidates actually were furnished with summer employment in laboratories through other means.

Results of the first summer's traineeships were remarkably encouraging; and for the summer of 1957 wider support was sought and obtained, so that the National Science Foundation provided about 30 traineeships in addition to 10 renewed traineeships from the National Institutes of Health. Miscellaneous support from hosts appreciably enlarged the funds available, so that in 1957, out of 87 applicants, 46 candidates were placed in research laboratories; 5 were renewals for trainees of 1956. Trainees were selected by the Education Committee with the assistance of Bowen, Daggs, Martin and Ronkin.

The traineeships are designed to spark the activities of college teachers in their acquaintance with research and its spirit, and possibly to initiate projects which they can subsequently pursue in their own institutions or at the host institutions. It is believed that the research interests that they formulate are reflected in their teaching and in their advice and encouragement to students. Administration of the traineeships proved to be time-consuming, since not only were applications received and reviewed, but considerable follow-up was required in order that trainees and hosts could give the Committee the benefit of their experiences. The Committee secured the part-time help of Daggs, the Executive Secretary of the Society. Expenses for administration also were paid from grants of NIH and NSF.

Small Research Grants

Encouragement to the continuance of research activities on the part of those who have received traineeships consists to a considerable extent in their ability to obtain supporting funds. A plan was launched to help trainees to secure initial research funds. Such funds are especially needed for items of research equipment and for assistance perhaps by part-time students. Grants up to $2000 are applied for to the National Institutes of Health by certain of the above trainees through the mediation of the Committee. In 1957 six such grants were activated.

Teaching Tour

The Committee recommended that a member of the Society should be requested to visit several teaching institutions in the interests of physiology teaching. His discussions with staffs and students visited would serve to stimulate interest and to disseminate data on the teaching problems being met elsewhere. The Council of the Society underwrote the expenses of the tour.

The first tour was made by Amberson in 1956. He chose to visit 20 institutions, mostly small colleges, in Ohio and North Carolina. He was especially concerned to ascertain the problems under which college teachers of physiology are laboring and to outline what might be done to promote their efforts. In general, he found (8) that little or no provision was made for research activities in the colleges, and that college teachers were isolated from one another as well as from the graduate schools to which their students might go. The teachers in the colleges seemed to appreciate his visits and the visits have supplied to the Committee more information about the situations that exist than any which has been obtained in other ways. A second tour, in the autumn of 1957, was shared by Martin and Adolph, in response to invitations from certain college and university departments.

In addition, the members of the Committee on Selection for summer trainees visited some of the host institutions where trainees were at work. In this fashion more contacts were made with college teachers and more information concerning their interests and problems was obtained. At the same time the attitudes of the host physiologists toward the summer traineeships were ascertained.

Physiological Survey of 1953

The second Survey, organized to study the currents of physiology, revealed additional problems of education in physiology. Most of the pertinent information (9) concerns formal instruction in physiology, such as the numbers of courses given, the numbers of students in these courses, and the numbers of graduate schools in which degrees in physiology are given. One important finding is that most students who have contact with instruction in physiology are registered as undergraduates. Only 12% of courses available are designed for students of medicine, for instance.

Roster of College Teachers of Physiology

In order to pursue the work of the Committee in assisting college teachers of physiology, Amberson undertook to build up a roster of college teachers of the subject. This was done chiefly by searching college catalogs and by sending letters to heads of biology departments. The roster has been enlarged; it is used in announcements of workshops and of traineeships and in connection with the teaching tours. It was found that only 25% of the persons on this roster of 1956 had been included in the distribution of questionaires by the survey of 1953; the remainder represents another population of physiologists.

Laboratory Instruction in Physiology

Included in the plans of the Committee on Education are attempts to search for stimulating and novel approaches to laboratory and conference instruction. The searches have concerned three chief areas: a) Medical Physiology, b) College Physiology, c) High School Biology. Area a has been incidentally pursued in the refresher courses. Some background in this area was obtained in the teaching session of April 1955, at which project methods were particularly emphasized as suitable for medical instruction in physiology. Area b has been organized by a subcommittee on laboratory outlines in college physiology (Prosser, Wilson, Tipton and Swenson). This subcommittee also collaborates with

the Committee on Educational Policies of the NRC Biology Council. The committee has collected a considerable number of exercises from diverse sources and has tested some of them for their general usefulness in college courses. Area c has not been pursued to date, and will be taken over by the AIBS Committee on Education, since it comprises a much wider area of interest than physiology.

Relations With Other Organizations

Federation. The Committee encourages other societies in the Federation to participate in some of the current programs. The American Society for Pharmacology and Experimental Therapeutics formally organized a Committee on Education which has studied means of furnishing information about careers in pharmacology. The Federation as a whole sponsored sessions for high school students and instructors in connection with the Federation meetings, beginning in 1955. This work was carried on under the Federation Committee for Public Information and served to bring to selected secondary school students and instructors some insight into what research in biological sciences attempts to do.

The American Institute of Biological Sciences is actively pursuing a program which concerns teaching. In 1956 members of our Committee attended a public teaching session of this organization. One of our Committee members is a member of its Committee on Education, which has actively sponsored teaching tours and workshops in the broader field of biology.

The American Association for the Advancement of Science has a Policy Committee on Education and has collected materials of background interest. In December 1956 our Society delegated to Hitchcock the organization of a joint session on the training of college teachers of biology. At this session five members of the Society spoke and took part in discussion.

Publication of Teaching Papers

Since its organization in 1953 the Committee has pressed actively for publication in the Society's own journals of materials in the area of teaching and instruction. At that time the Journal of Applied Physiology opened its pages to papers which had to do with teaching equipment in the laboratory. The organization of the President's Newsletter supplied a definite place for publication of papers of teaching interest (10); the first full-length paper was published in the fall of 1956. The Physiologist plans to carry articles on teaching. It is felt to be important that publications on educational matters be represented in the Society's own publications and not be relegated to separate publications outside the Society.

Library of Physiology

An exhibit of books (research monographs) of interest particularly to teachers of college physiology was gathered by the Committee. This set of books was exhibited at the workshops and will be exhibited at meetings of the Society. The exhibit is selective rather than inclusive and covers considerable breadth in the field of physiology; it brings teachers into more intimate contact with advances and comprehensive

treatments of the science. The list of these books was recently distributed to APS members.

Recognition of Teaching Effort

The Committee feels that a means of encouraging some of those who teach physiology and biology consists in suitable recognitions. It is believed that awards should be arranged within the Society, but what form such awards should take has not been agreed on. It is believed that specific recognition of teaching effort can be placed on a par with recognition of research effort, and may ultimately lead to Society membership. At the same time it is clear that the techniques for deciding where this effort has been made have not been cultivated very widely and need to be cultivated before suitable awardees can be chosen.

GENERAL STATEMENT

All the above projects are continuing (11, 12) and termination of any one of them depends on definite achievements of satisfactory goals.

The general policy of the Committee has been to pursue those few projects that have been clearly defined. This policy automatically gave priority to a limited number of efforts out of the almost infinite number of projects that seem available. It also limited automatically the number of projects to those that could be adequately handled. Financial considerations have played some influence, as was the case in the traineeship program, which blossomed because funds were offered for its support.

No evaluation of results of the Society's efforts in education can be made. Enthusiastic responses have been obtained, particularly from participants in the workshops and from participants in the traineeship program. Certain results can be seen in the changes of attitudes on the part of Society members, tending toward the feeling that teaching is an important activity. The Committee believes that teaching can take its place side by side with research in the ambitions and thinking of physiologists in general.

A present hope is that individual Society members will do those things for the vitality and worth of teaching that no organization can accomplish.

A future hope is that a stage will be reached where teachers will no longer need aid and encouragement. At this point the Committee's job will be finished, but this point may, unfortunately, be long in arriving.

REFERENCES

1. History of the American Physiological Society: Semicentennial. Baltimore; Williams & Wilkins, 1938.
2. Physiology in North America, 1945: Survey. Fed. Proc. 5: 407-436, 1946.
3. DOW, P. Digest of Comments and Suggestions from the Survey. Mimeographed, 8 pp., 1946.

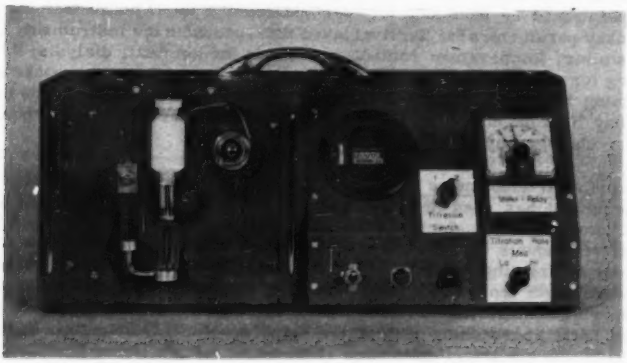
4. Report of Committee on Teaching Problems in Physiology. Fed. Proc. 6: 522-537, 1947.
5. In: Programs of Annual Spring Meetings, APS. Fed. Proc. 10: 1951, to date.
6. COMROE, J. H. J. Med. Educ. 30: 219-220, 1955.
7. In: Programs of Annual Fall Meetins, APS. Printed by Local Committees, 1954 to date.
8. AMBERSON, W. R. President's Newsletter, APS, Spring 1957, pp. 13-16.
9. Survey of Physiological Science in 1953. Washington, D.C.: Am. Physiol. Soc. In press.
10. Report, Items from Committee on Education. President's Newsletlet, APS. Issued semiannually (mimeographed), 1953 to date.
11. Activities of APS Committee on Education. Fed. Proc. 16, No. 1, Part II, liv-lviii, 1957.
12. A set of documents representing the work of the APS Committee on Education is available in the Society's Office.

New Instruments for Physiologists

By Alfred Henley

National Instrument Laboratories, Inc.
Washington, D. C.

Chloridometer. A new instrument for automatic and accurate determination of chloride concentration in serum, urine, and tissue extracts has been developed by Ernest Cotlove, Hillary V. Trantham, and Robert L. Bowman, the National Heart Institute, National Institutes of Health, Bethesda, Md. In a proving out period of more than a year at NIH, the Johns Hopkins Medical School, and other research centers, the Chloridometer showed important advantages of sensitivity and simplicity over the commonly employed colorimetric and electrometric methods. The instrument uses an amperometric end-point to obtain automatic shut-off at a pre-set increment of indicator current. Generator electrodes in the coulometric circuit release silver ions into the



titration solution at a constant rate. When all chloride is precipitated, the increasing concentration of free silver ion causes a rising current to flow through the indicator electrodes and the pre-set meter-relay stops the timer, which runs as silver ions are generated. Since the rate of generation of silver ion is constant, the amount of chloride precipitated is proportional to the elasped time. Three ranges of chloride content are provided for and as little as 0.25 microequivalent of chloride can be measured accurately.

Pulmonary Function Laboratory. The usual complex and costly equipment for making tests of pulmonary function is now combined in a complete laboratory and clinical apparatus. Using the constant volume closed circuit scheme, the instrument is reportedly successful in the study of static lung volumes, pulmonary ventilation, intrapulmonary gas transfer, physical properties of the lungs, and the special technique of

* An article on new instruments will be a regular feature appearing in each issue.

bronchospirometry. Operation is said to be simple and to require no special skill or knowledge.

Body Volume Determinator. An apparatus for measuring human body volume is based on a unit designed by William E. Siri, Donner Laboratory, University of California. As one of the few non-immersion body volume determinators, the apparatus is described as greatly superior to instruments which measure pressure or volume changes and with which only limited success has been achieved. With available accessories CO_2 output, oxygen uptake, and total volume may also be measured and the metabolic state of the subject accurately determined. The entire apparatus is divided between a sealed body chamber of 400-liter volume in which the patient takes a seated position and a control cabinet which houses the power supply and the potentiometer and recording circuits.

Perfusion Apparatus for the Study of Isolated Organs. An ingenious perfusion apparatus originally designed 10 years ago by Joseph A. Long has now been improved and simplified by William R. Lyons, the Institute of Experimental Biology and the Department of Anatomy, University of California. That organs like the young rat liver have been maintained by perfusion for periods from 4 to 27 hours indicates the many parameters for survival taken into account in the instrument. Peristalsis, temperature control, provision for nutrient, dialysis, filtering for particulate matter, atmospheric pressure, and even pockets for doing blood chemistry are furnished for the isolated organ. The organ may be kept under continuous microscopic observation and in position for photography.

Arteriovenous Oxygen Difference Recorder. A photoelectric instrument has been designed by Arthur C. Guyton and colleagues at the University of Mississippi School of Medicine to record continuously the arteriovenous oxygen difference in animals. It operates by automatically subtracting the optical density of arterial blood at 640 millimicrons wavelength from the optical density of venous blood at the same wavelength. Calibration curves indicate that the instrument has an accuracy at least approaching that of the Van Slyke-Neill manometric analysis. Also, the electrical difference of the recorder is a linear function of the arteriovenous oxygen difference.

Electronic Lesion Maker. In order to study quantitatively the chemical changes which take place in a specific tissue during acute inflammation, it is important to apply a standard reproducible lesion. The usual technique of injecting a chemical irritant has been found to be slow, difficult, and sometimes unpredictable. Bernard K. Forscher and Harold R. Stanley of the National Institute of Dental Research, National Institutes of Health, have devised a method to produce lesions by the controlled application of radio-frequency current. Electrodes are specialized for size and intensity of different lesions, the commercial model of the instrument being furnished with three frequently used types.

Phosphene Generator. An instrument whose validity is now being widely tested holds the possiblity of a simple and rapid test for glaucoma by attempting to correlate the color of the phosphene pattern seen by the subject with the degree of intraocular pressure. With this instrument a small voltage at low current is applied bitemporally and the subject sees a light flash, or "phosphene." A bluish-white phosphene

is observed with the normal eye, while in the case of increased intraocular pressure the patient reports yellow, orange, or red phosphenes. An apparent shift toward the longer wavelengths of the spectrum occurs with increased pressure. Inventor of the device is Carroll E. Humphrey, Applied Physics Laboratory, Johns Hopkins University. Experimental screening of typical population groups is being initiated in several cities, including Washington, D. C.

Address a post card to New Instruments for Physiologists, American Physiological Society, 9650 Wisconsin Avenue, Washington 14, D. C., for further information about any item described above.

The Social Responsibility of the Biological Scientists

By L. N. Katz, President

It has been the custom of the American Physiological Society to have its President send a message to its membership. For the most part this has dealt with particular aspects of the organization which at the moment seemed troublesome. I would like to depart from this tradition and deal with a broad philosophical aspect. Because of the tremendous impact of science on our economy and on our defense effort in relation to the Soviets this has been brought more forcefully to our attention in recent months. It is apparent that for scientists there will be an upsurge in recognition and opportunity.

A movement is under way to recruit future scientists at the high school and college level. Appreciation of the creative possibilities of basic research, as distinct from applied research and development, is finally beginning to impress the American people. I am sure that what we are seeking in this country is the same urge for scientific development which permeates the Soviets without paying the penalty of centralized dominance and dictation. All of us must have thought of this, as I have, many times recently.

This enhancement of opportunity, prestige and influence for scientists brings to the fore our moral obligation as citizens. This is an action not only for the few with political experience but for every scientist -- and this includes the biologists. Each can work in his own community to bring a proper perspective to other citizens from the business, professional and labor worlds as to what is science, as each of us interprets it. We should explain its ego-satisfactions and its responsibilities to the community -- and also the community's responsibilities to science.

Operating in civic groups, in Boards of Education, in Parent-Teacher Associations and so forth, scientists have a rare opportunity to round out the thinking of our local communities into a unified entity in which science neither plays too great, nor too small a role. We cannot leave to educators, politicians, or "do-gooders" the role of interpreting science to the public. We, ourselves, must do it in our neighborhoods, our schools, our churches, our local political subdivisions, and our communities. With such a broad base in the "grass roots" we can have the foundation upon which the individual States and the Nation can operate most effectively in the field of science.

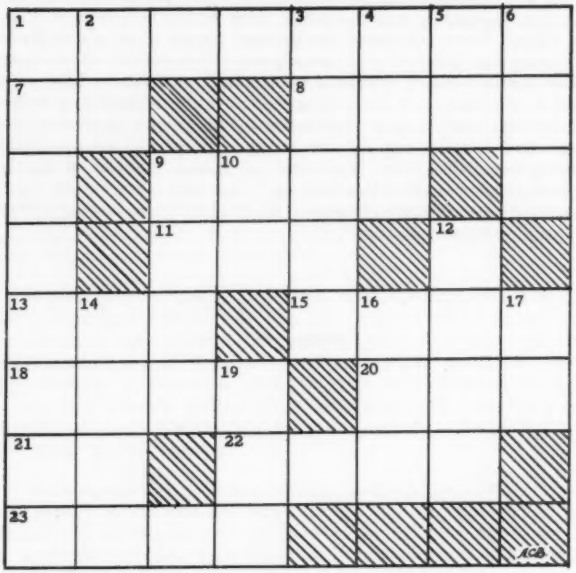
There has been a vacuum in this regard because too many scientists have felt it was not their responsibility to deal with the public, or even with their local schools. But this is an error. Each of us, in his or her own way, must deal with the reality that science is a potent force for good in our society and that it is here to stay. The scientist with the business man, the laborer, the politician and the military, must help to carve out our destiny. We scientist cannot shirk this task. If we do, the dangers of the luxury of living only in our "ivory towers" are far too great.

I think it is fair to state that among the scientists in this regard,

the biological scientists, of which our own Society is representative, have perhaps been more backward than those in physics and chemistry.

Life processes are as vital to our civilization as the laws of physics and chemistry and the public must be made aware of it -- and quickly. Now, I believe most firmly that there is as much diversity among biological scientists as among any other portion of our population as to mores, creed, political opinion and motivation. But we have one thing in common with other scientists --an understanding of the experimental approach and the know-how by which new knowledge can be created. And presumably we are more rational and not as emotional as other groups. We can, if we will, on this account be of service to our communities, each in his own way, but only if we add to our other burdens the responsibility of helping to mold our American civilization in the troubled times ahead.

A PHYSIOLOGICAL CROSSWORD PUZZLE



Across

1. This member of APS shared a Nobel prize for using 1 down
7. One of the cardiac nodes
8. Gone to the Federation meetings
9. It is said to be impossible to have this and eat it too
11. Correlated with arteriosclerosis
13. Brain waves
15. A form of perfusion
18. Family _____
20. Szent-Gyorgyi says this is important
21. Two-thirds of an egg
22. Cell
23. You do this in the Eve method of resuscitation

Down

1. See 1 across
2. One-half of an egg
3. If you were this,
   your hypothalamic centers would be stimulated
4. We regard the great physiologists with this
5. Must be a resident of, to be a member of APS
6. T-1824
9. Physiologists usually keep 16 down in this
10. Blood protein ratio
12. 16 down can give a nasty one
14. Energo plus zero
16. Wistar white
17. Precipitate
19. Famous for a fistula

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